The Journal of Bone and Joint Surgery

The Official Publication of
The American Orthopaedic Association
The British Orthopaedic Association
The American Academy of Orthopaedic Surgeons
The Australian Orthopaedic Association
The Canadian Orthopaedic Association
American Society for Surgery of the Hand
New Zealand Orthopaedic Association
South African Orthopaedic Association

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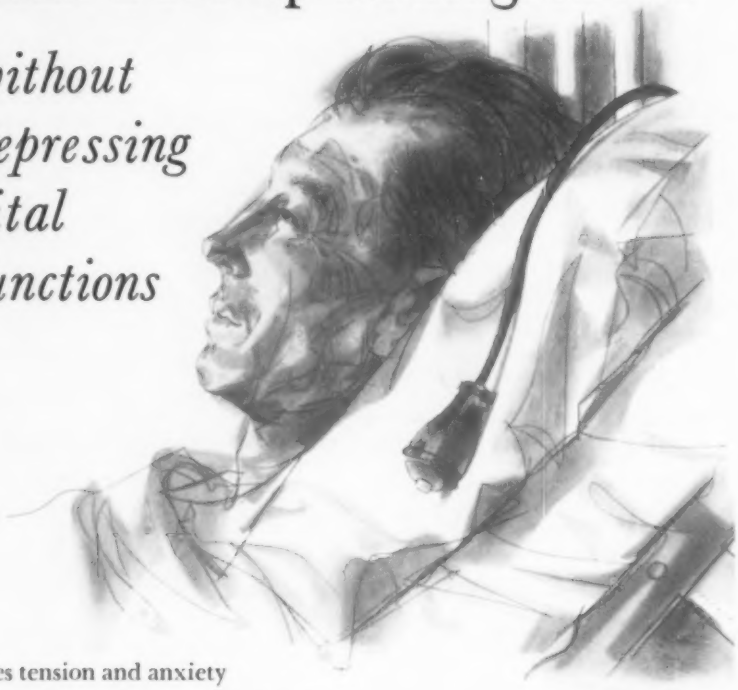

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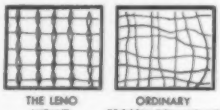

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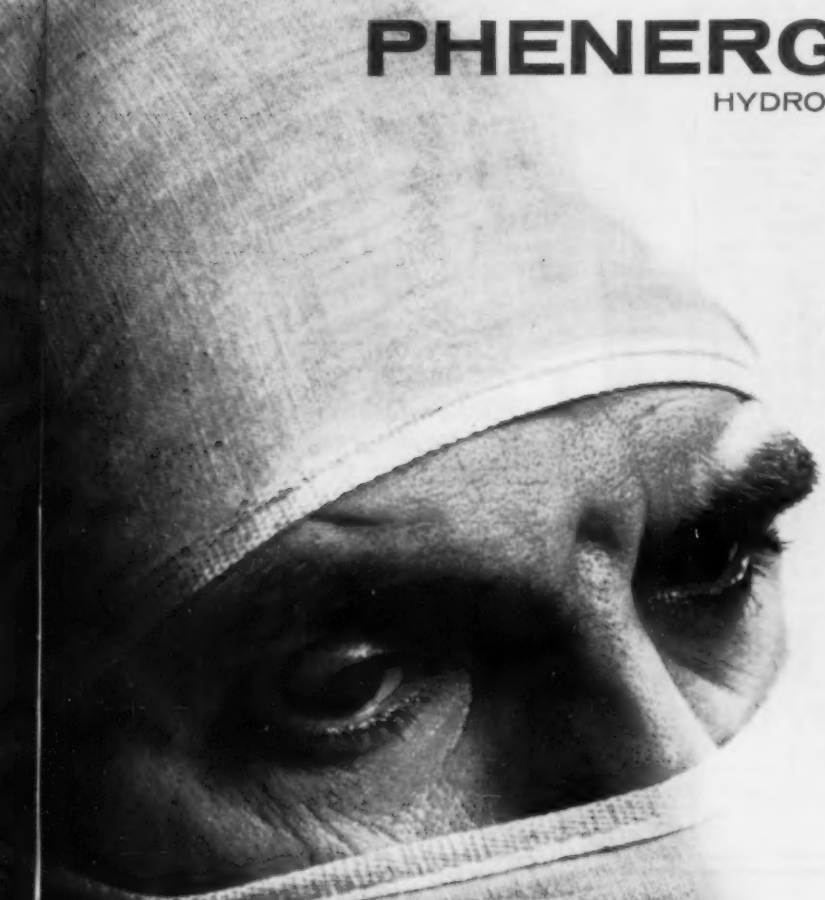

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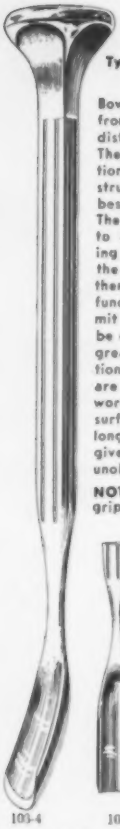

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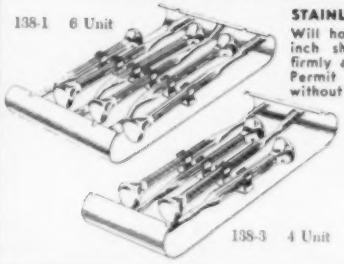

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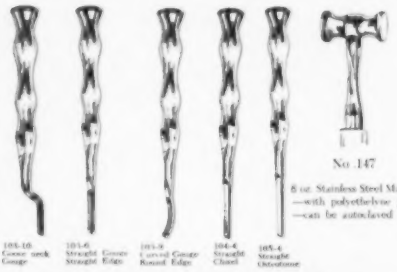

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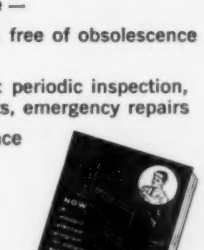

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When accidents result in sprains or strains, PARAFLEX reduces painful spasm promptly. Effective in a wide variety of rheumatic, arthritic and orthopedic disorders, PARAFLEX relieves pain, improves mobility and facilitates rehabilitation. Side effects seldom occur and are rarely severe enough to require discontinuation of therapy. □ *Average Dosage:* Two tablets t.i.d. or q.i.d. □ *Supplied:* Tablets, scored, orange, bottles of 50. Each tablet contains PARAFLEX, 250 mg.

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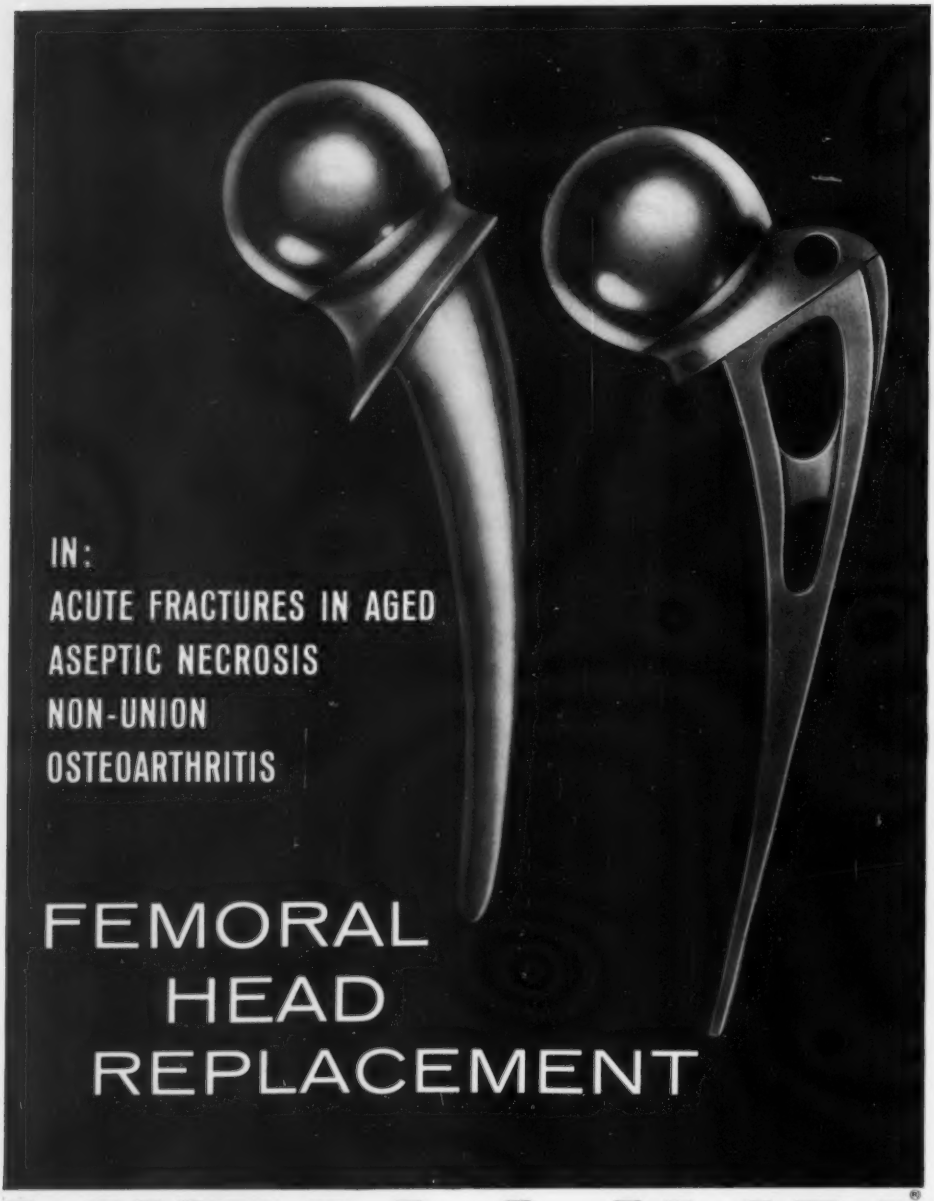

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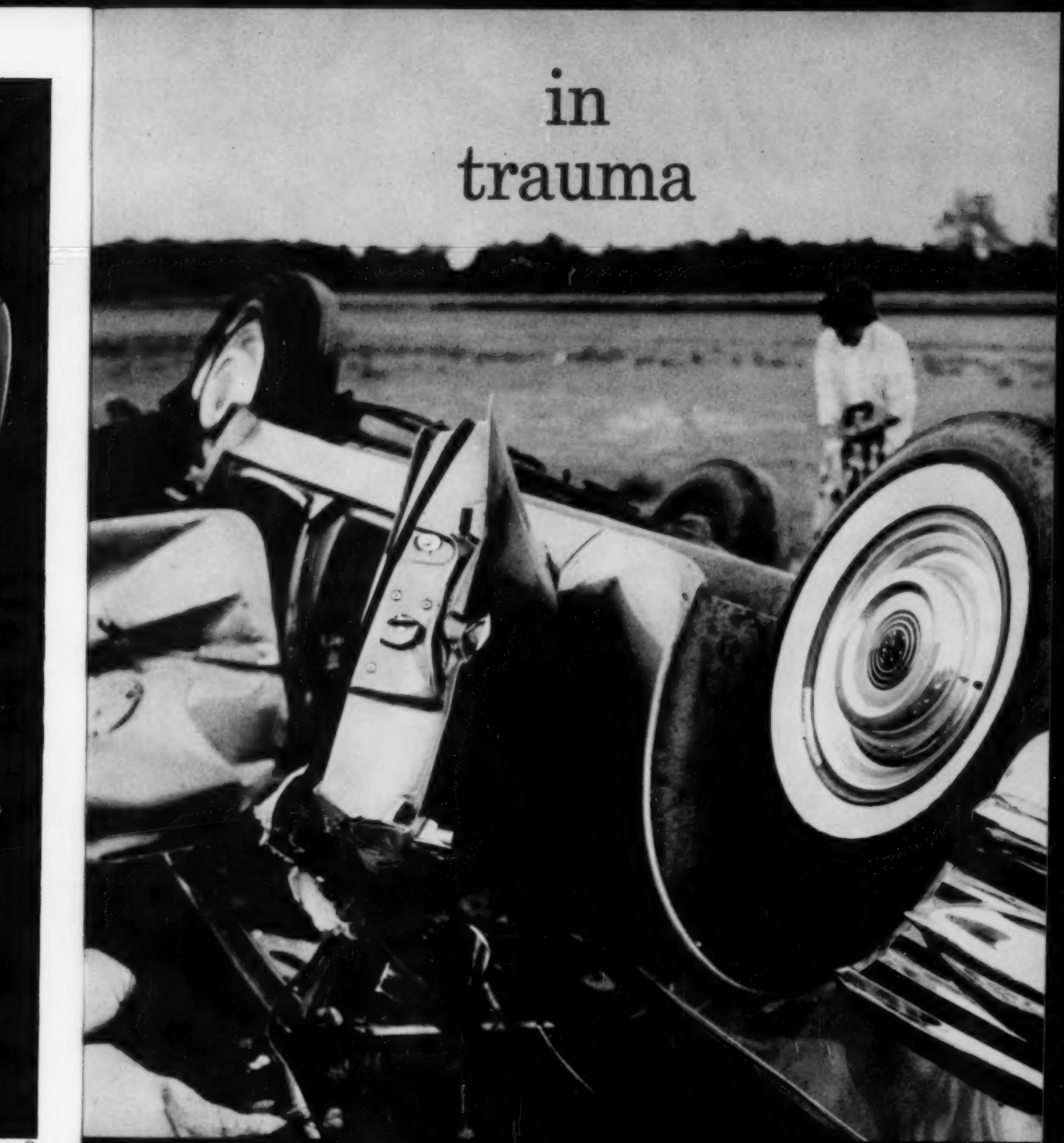

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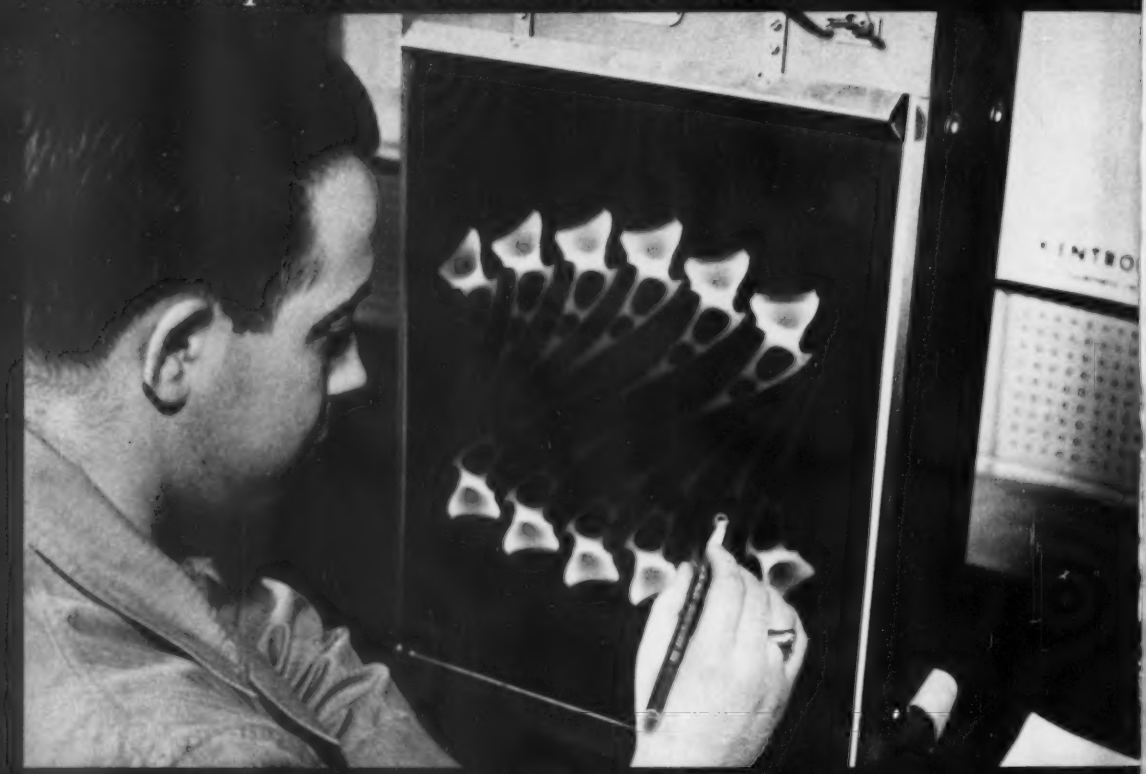
prostheses are inspected inside and out...



X-raying is one of the more than ten standard inspections of Vitallium hip prostheses.

"... Vitallium, up to the present time, has proved superior to the use of steel or other metals or plastics. Not only is Vitallium a satisfactory metal, but the company producing the appliances is using more than ordinary skill, care, and know-how, to produce a dependable product."

Thompson, F. R.: *In* Am. Acad. Orthop. Surg., Instructional Course Lectures, V. 16, C. V. Mosby, 1959, p. 209.

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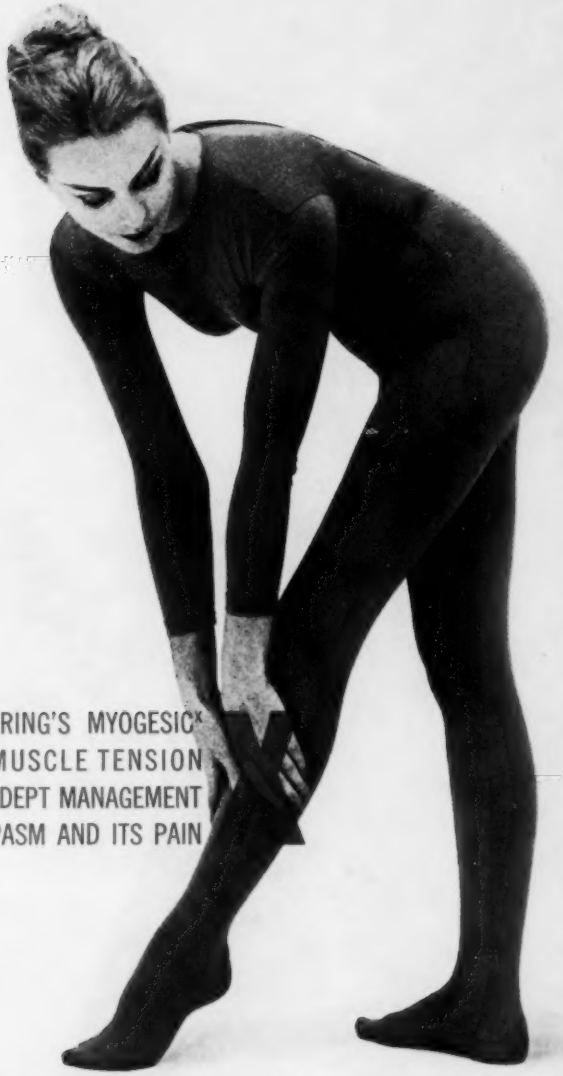

NO SPRAIN, NO STRAIN, OR LOW BACK PAIN

can resist the rapid relaxant relief of

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RELA—SCHERING'S MYOGESIC[x] RELAXES MUSCLE TENSION FOR MORE ADEPT MANAGEMENT OF BOTH SPASM AND ITS PAIN

Rela is most useful in the areas where narcotic analgesics are unwarranted and where salicylates are inadequate. Its muscle-relaxant properties are dependable yet significantly free of the limitations or problems often associated with other relaxants.

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M-287

1. Kuge, T.: To be published.

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MANY MOUNTAINOUS FRACTURE PROBLEMS CAN BE MADE INTO SIMPLE ONES WHEN RUSH PINS ARE PHYSIOLOGICALLY APPLIED.

Proper application of the RUSH PIN is not always easy. It takes a while to learn. It is quite different in principle and technic from other forms of medullary fixation. It is not designed to impact the marrow cavity, but to accurately transfix the fractured bone by points of pressure, precisely applied.

The ingenious surgeon, who has added this to his knowledge and skills, has simplified his tasks and contributed pleasure to his patients. He minimizes surgery and speeds convalescence with unbelievably early motion, even in fractures near joints. Removable splints are sometimes used, but casts or traction, rarely.

**"The Rush Medullary Pin" and "Berivon" are registered trademarks of The Berivon Company*

In answering advertisements, please mention *The Journal of Bone and Joint Surgery*.

Because:

Every severe fracture has its characteristic deformity. You might call it muscle pull or intrinsic dynamic forces, but it is a deforming force.

For good fixation this force must be overcome. The muscle pull of the extremity must be utilized to advantage to provide contact compression. This is why the RUSH PIN came into being.

It was designed to exert a dynamic force of its own to resist this deforming force. It was designed to be introduced from the side of the bone, rarely from the end.

The **point** must drive through cancellous bone, deflect from the cortex, drive and guide easily, yet be effective in locking the distal fragment against rotation. That is why the RUSH PIN has the SLED RUNNER POINT.

The RUSH PIN must not impact the marrow cavity, but must lock the bone by points of pressure. That is why it must have exactly the right resilience. That is why it is made only of **Type 316 stainless steel of precise temper,** hand fashioned, cold worked and electropolished.

It required 15 years clinical research to perfect the design of the RUSH PIN and two years to perfect the proper temper for its metal.

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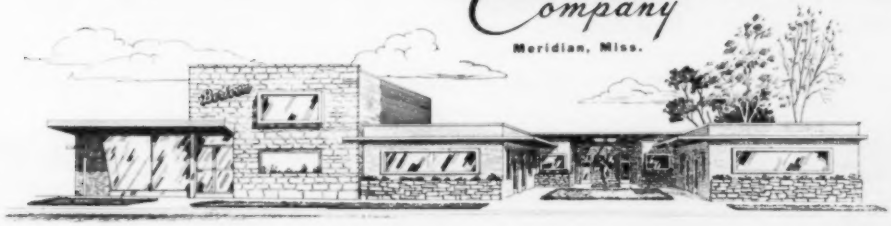

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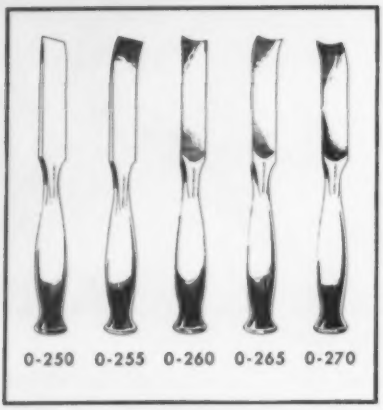

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CASE 0-295—holds seven Smith-Petersen Osteotomes.

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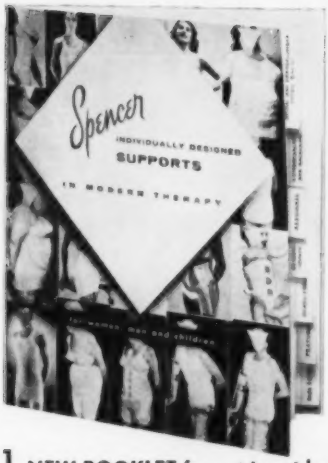

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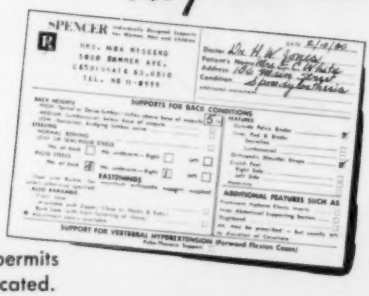

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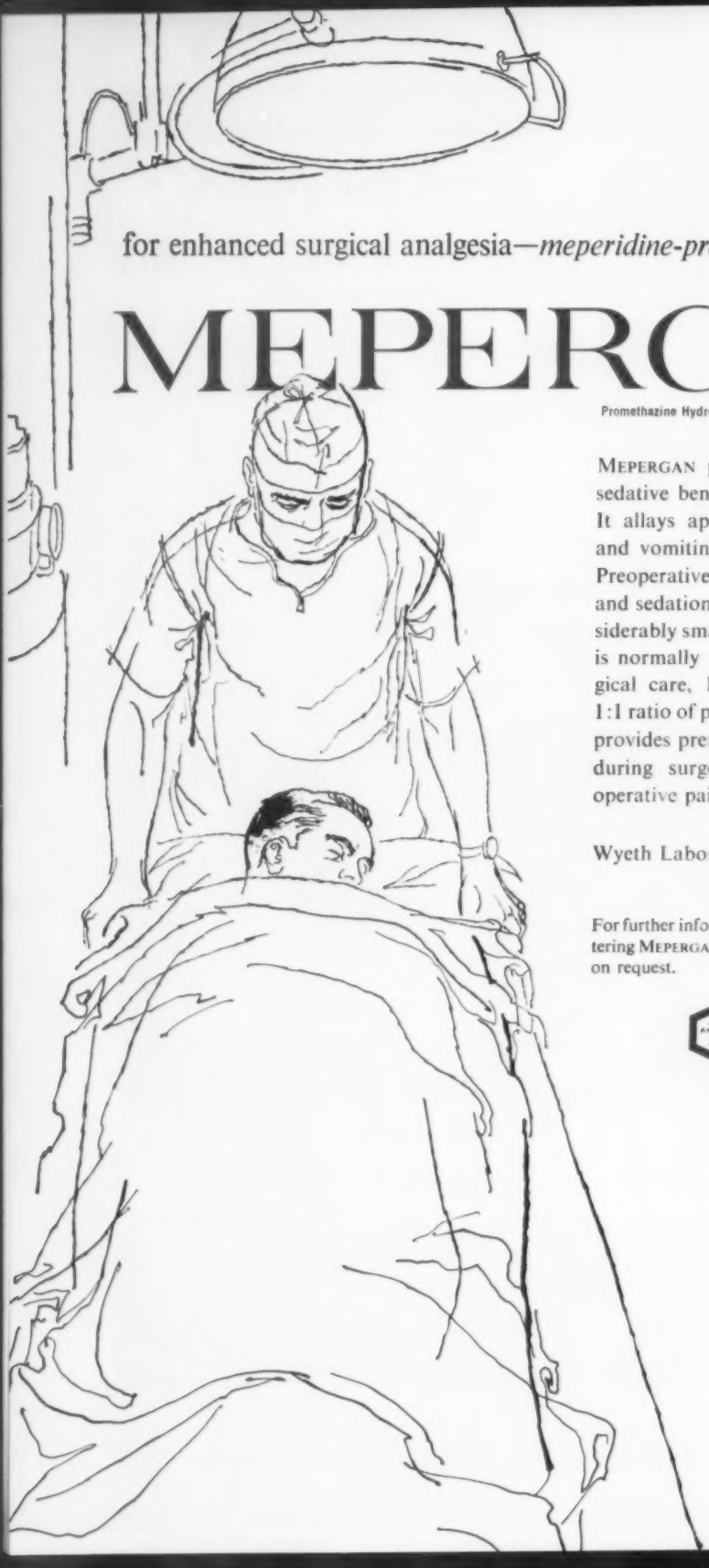

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MEPERGAN provides both analgesic and sedative benefits for the surgical patient. It allays apprehension, controls nausea and vomiting, and facilitates anesthesia. Preoperative and postoperative analgesia and sedation may be attained with a considerably smaller dose of the narcotic than is normally used. For inclusive perisurgical care, MEPERGAN—with its proved 1:1 ratio of promethazine to meperidine—provides premedication, anesthetic action during surgery, and control of postoperative pain.

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For "sag" control—the lower layer of springs pushes up against the bedboard and prevents "sagging" at any point.

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The unique construction of Back Care® —including the new "Ortho-Fiber" bedboard—was suggested by physicians who stressed the need for a mattress especially adapted to the requirements of patients with chronic backache.

Back Care has been tested and approved by a group of leading orthopedic surgeons. They found that it affords patients both the firmness and the comfort necessary to alleviate backache caused or aggravated by lack of proper mattress support.

Many physicians have endorsed Back Care with Built-in Bedboard, as a basic adjunct to the management of chronic, uncomplicated backache.

For complete information on Back Care —with special reference to its orthopedic features—write for the descriptive booklet from Simmons Co., Dept. AA, Merchandise Mart, Chicago, Illinois.

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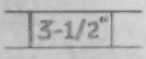
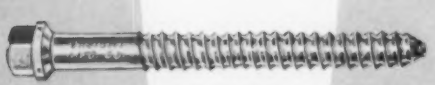


SIZES MARKED ON EACH PIN



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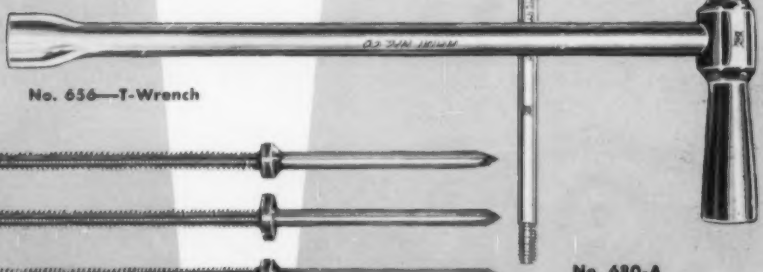

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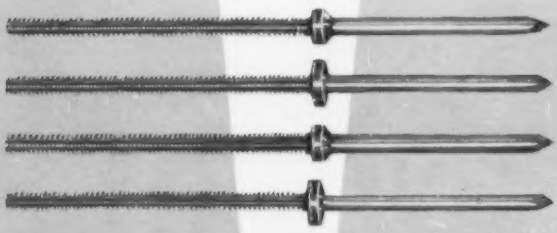

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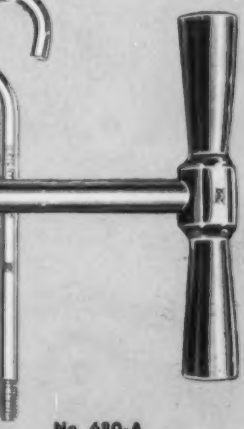

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"Orthopedic shoes parents can afford . . .

CHESBROUGH Corrective Pre-Walkers"

No. 1400 OPEN TOE. Straight-line symmetrical last, firm heel, no back seam. Adaptable to Denis Browne Splints.

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"When a child in my own family needed a corrective shoe, I discovered what a strain it can mean to a family budget, because 1) corrective footwear is expensive and 2) frequent purchase of new corrective shoes is required. Then and there I decided there was a real need for a moderately priced corrective shoe —a shoe parents could afford. That's why and when Chesbrough Orthopedic Pre-Walkers were born.

"Our 60 years of shoe-making experience resulted in corrective Pre-Walkers of scientific design, expert workmanship, fine leathers combined with orthopedically correct lasts to provide necessary correction at an economical price."

Today—just three years later—orthopedic specialists in 45 states and several foreign countries are prescribing these shoes.

All shoes in unlined white elk, sizes 000 to 4, narrow and wide. Available in full pairs, split pairs or single shoes (no extra charge for half pairs).

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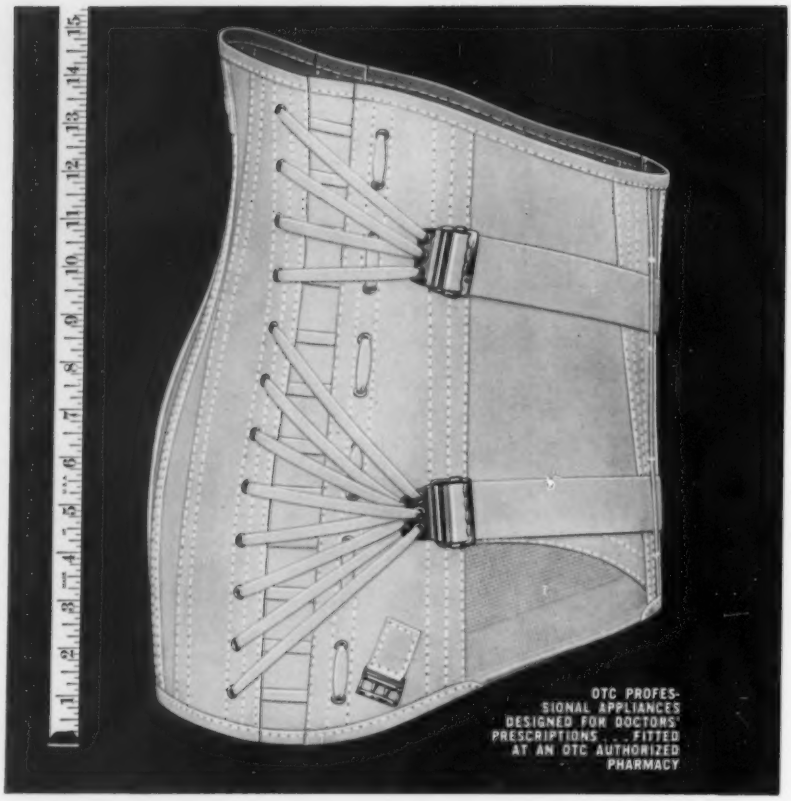

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Here is the sacro-lumbar support particularly designed for stabilization of the entire lower spine . . . OTC Model 829-HS.

The deep 15″ back will cover as high as the eighth dorsal vertebra in the average patient, and as high as the tenth in even the very tall. In the back, multiple flexible stays and two rigid shaped steels deliver stabilizing support to the entire lower spine. Two sets of pull straps control the encircling pressure.

Whatever OTC Support or Orthopedic Appliance you prescribe, you and your patient can always expect these benefits:

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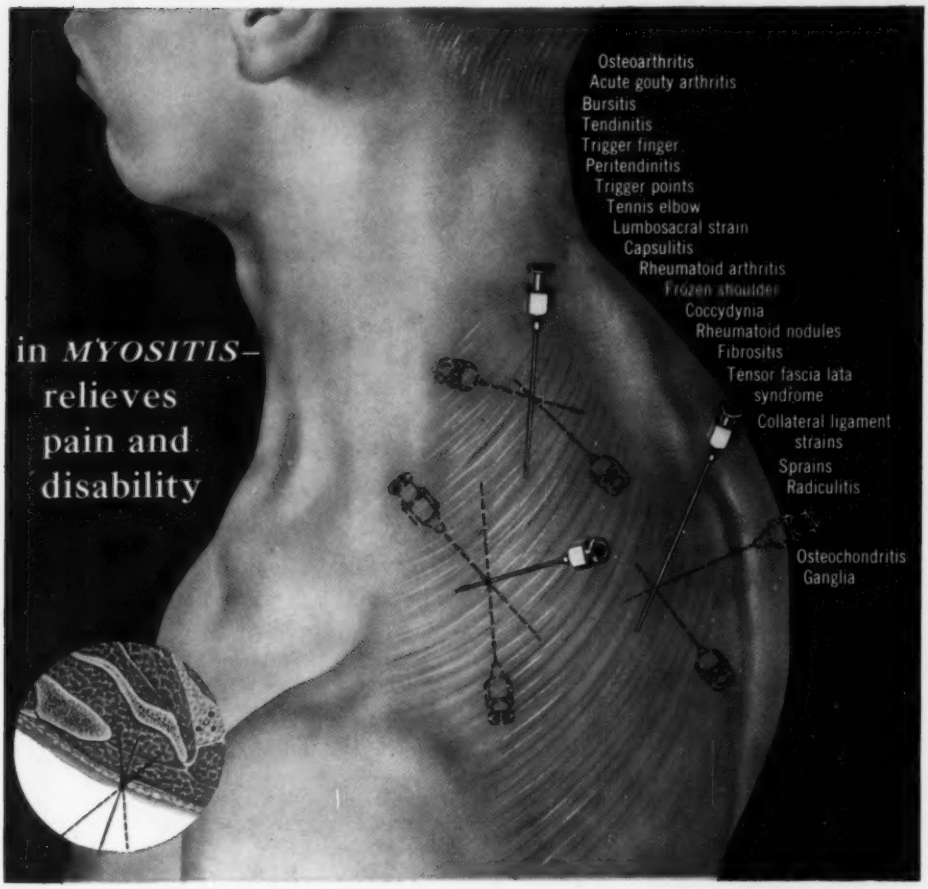
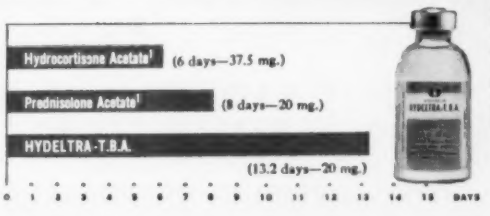
(Prednisolone *tertiary*-butylacetate, Merck)

for relief that lasts—longer



Anti-inflammatory effect lasts longer than that provided by any other steroid ester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HYDELTRA-T.B.A.
(13.2 days—20 mg.)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 DAYS

Dosage: the usual intra-articular, intra-bursal or soft tissue dose ranges from 20 to 30 mg. depending on location and extent of pathology.

Supplied: Suspension 'HYDELTRA'-T.B.A.—20 mg./cc. of prednisolone *tertiary*-butylacetate, in 5-cc. vials.

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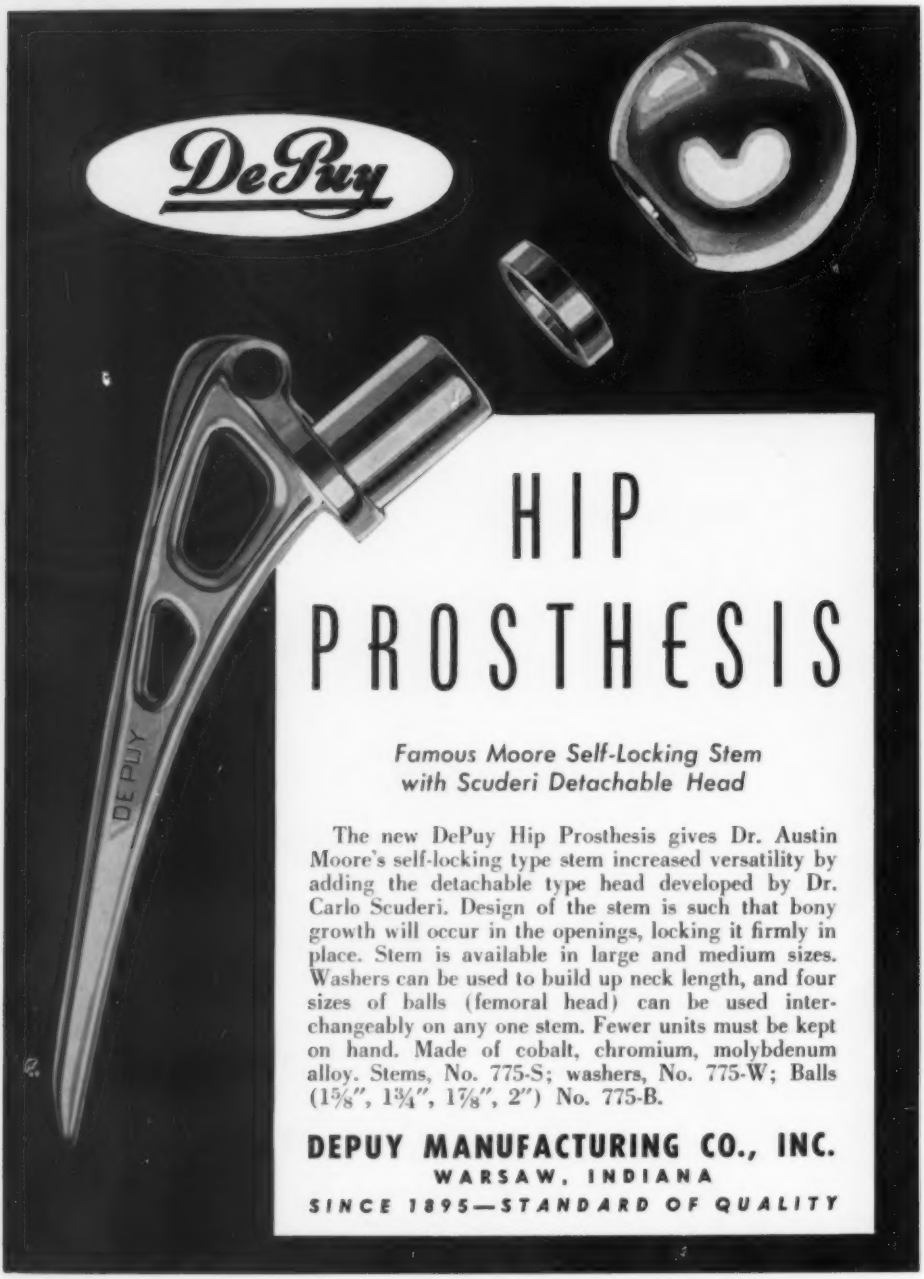

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Famous Moore Self-Locking Stem with Scuderi Detachable Head

The new DePuy Hip Prosthesis gives Dr. Austin Moore's self-locking type stem increased versatility by adding the detachable type head developed by Dr. Carlo Scuderi. Design of the stem is such that bony growth will occur in the openings, locking it firmly in place. Stem is available in large and medium sizes. Washers can be used to build up neck length, and four sizes of balls (femoral head) can be used interchangeably on any one stem. Fewer units must be kept on hand. Made of cobalt, chromium, molybdenum alloy. Stems, No. 775-S; washers, No. 775-W; Balls (1⅝", 1¾", 1⅞", 2") No. 775-B.

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WARSAW, INDIANA
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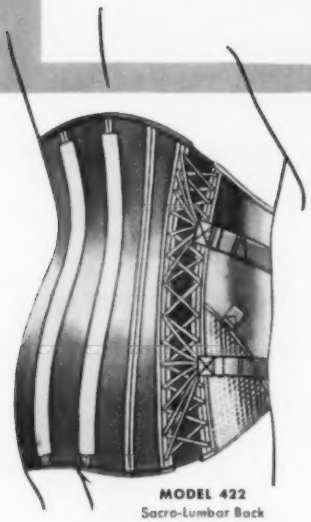
Prescribe Freeman Scientific Corset-Type BACK BRACES



MODEL 422
Sacro-Lumbar Back Support For Men
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Therapeutic benefits associated with various types of steel braces may be achieved with fine Freeman corset-type supports. For 68 years, Freeman has consulted with orthopedic surgeons to provide this scientifically designed Back Support that permits easy adjustment to brace your patient in any degree to almost complete immobilization.

Your patients will appreciate the unsurpassed tailoring and excellent fit of Freeman back braces that provide the utmost comfort in sitting, standing and reclining positions. And they'll welcome the bonus luxury of Freeman's soft, comfortable interior finish that avoids irritation. Exterior is made of Pima Cotton and Dacron Fabric.

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Freeman makes Full-Fashioned Elastic Hose and a complete selection of Maternity Garments in addition to . . .

- **ABDOMINAL SUPPORTS**
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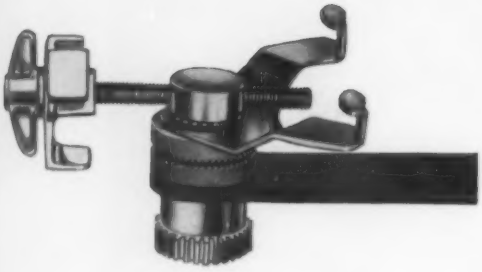

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1. Precision die cast Serrated Discs permit 50 positions.
2. New Knurled Screw locks discs in position.
3. New Triple Flange fits club foot shoes or any sole thickness.
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6. Lengths 6, 7, 8, 9, 10, 12, 14, 16 and 18 inches. Special lengths to 30 inches at no extra cost.

ORTHOPEDIC SURGEONS recognize the decided advancements this versatile splint affords in treating club feet, positional deformities, tibial torsions, flat feet and congenital hip dislocations. Also applicable for any other deformities that are actively corrected by incessant kicking.

Very little adjustment by surgeon or orthotist is required to fit and position this new Fillauer Detachable Splint.

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BOX 1678 CHATTANOOGA, TENN.
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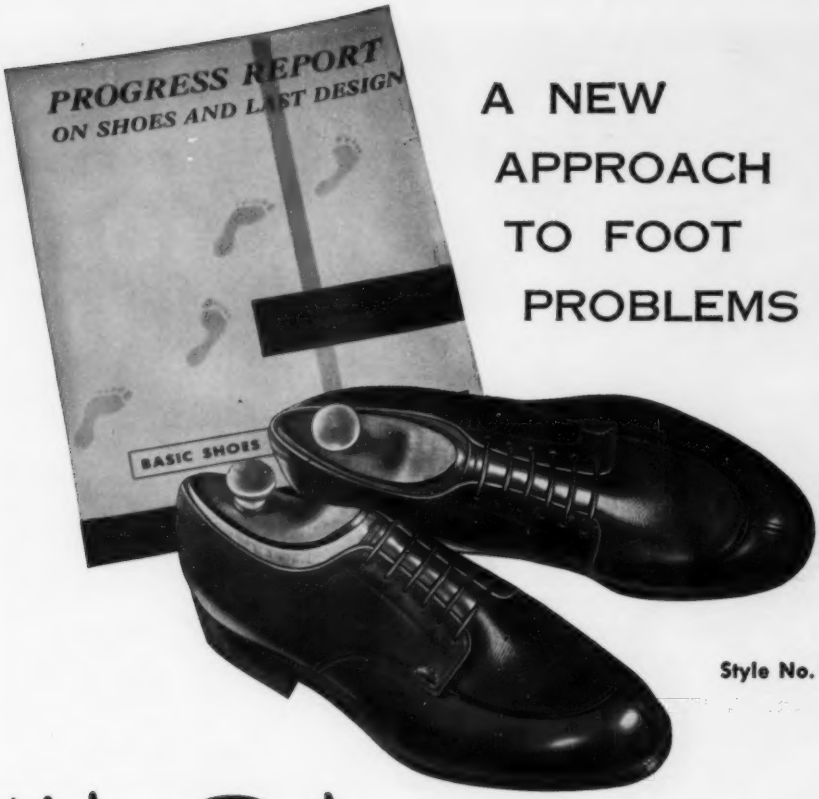

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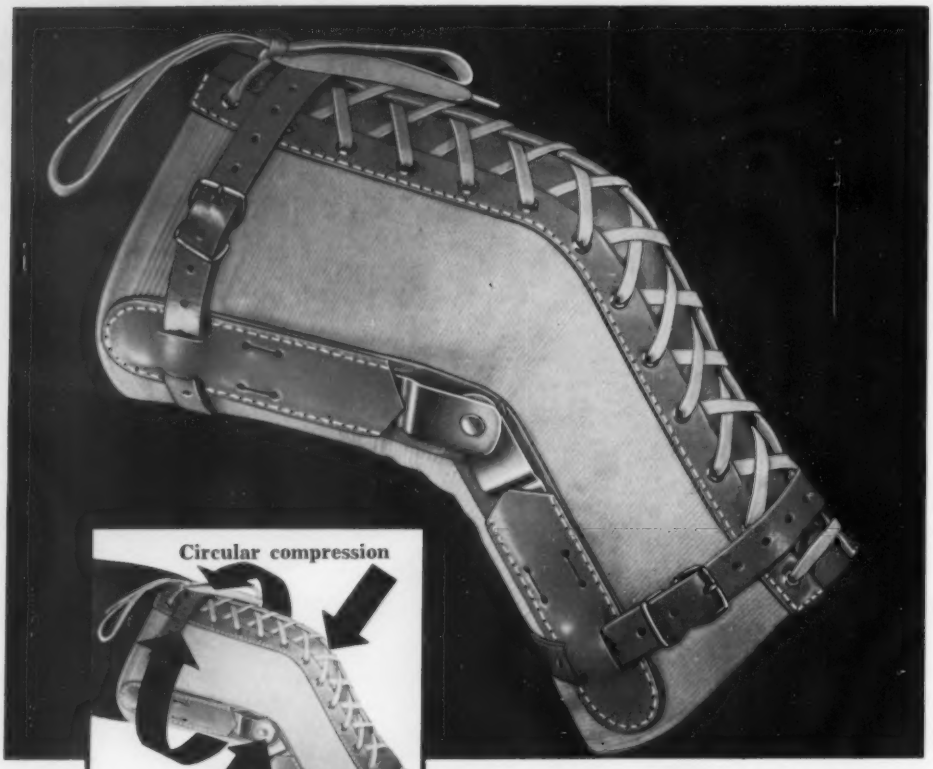

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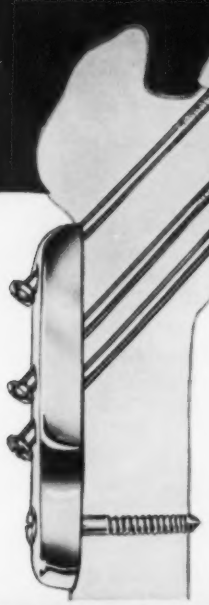

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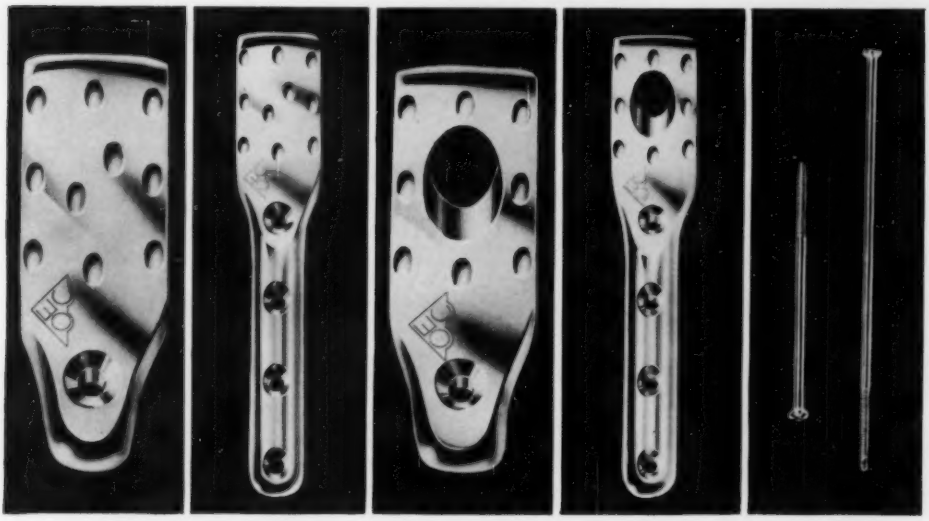

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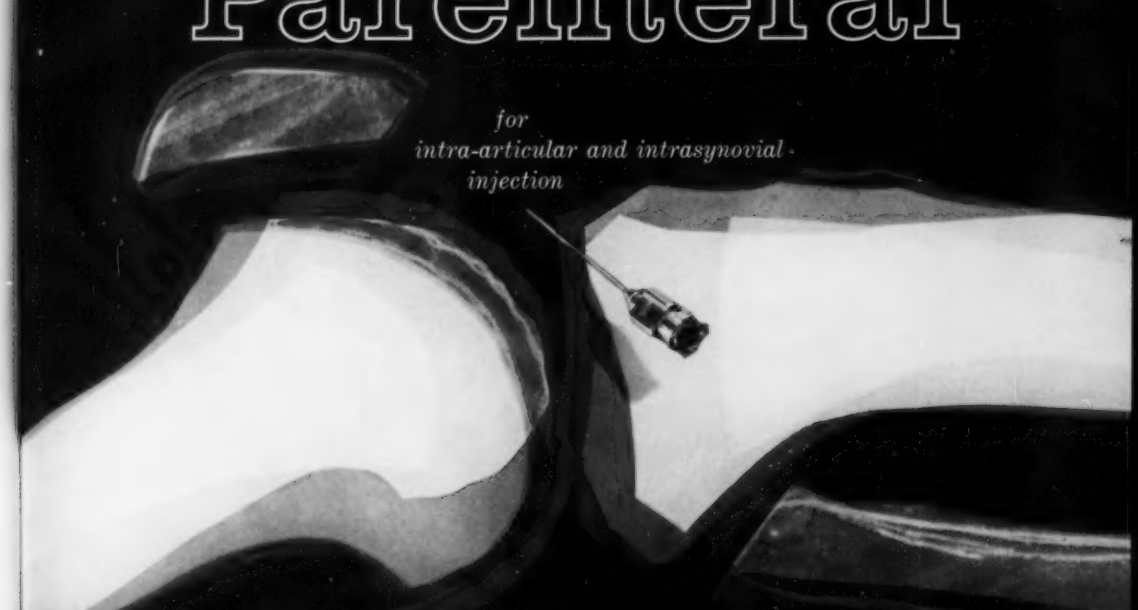

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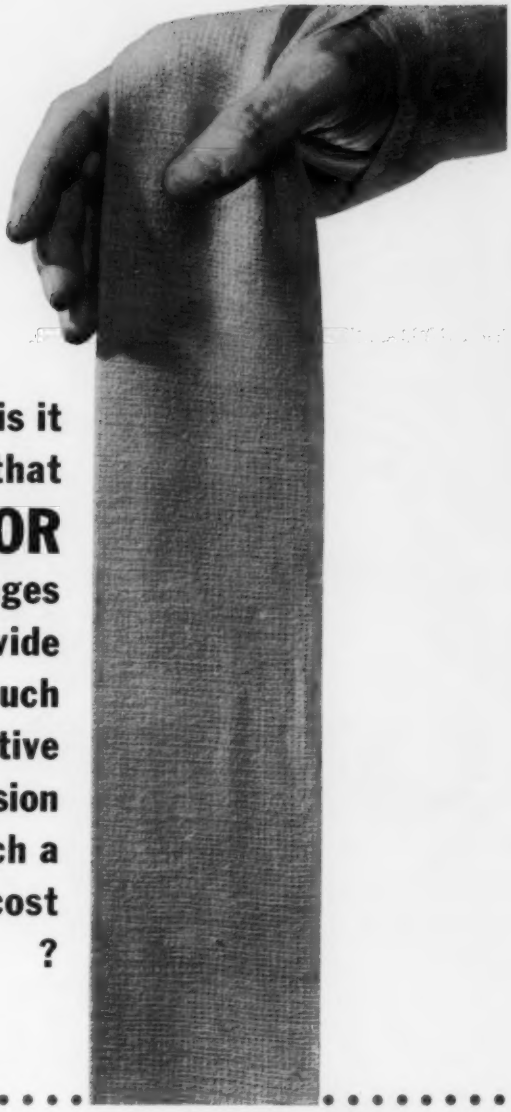

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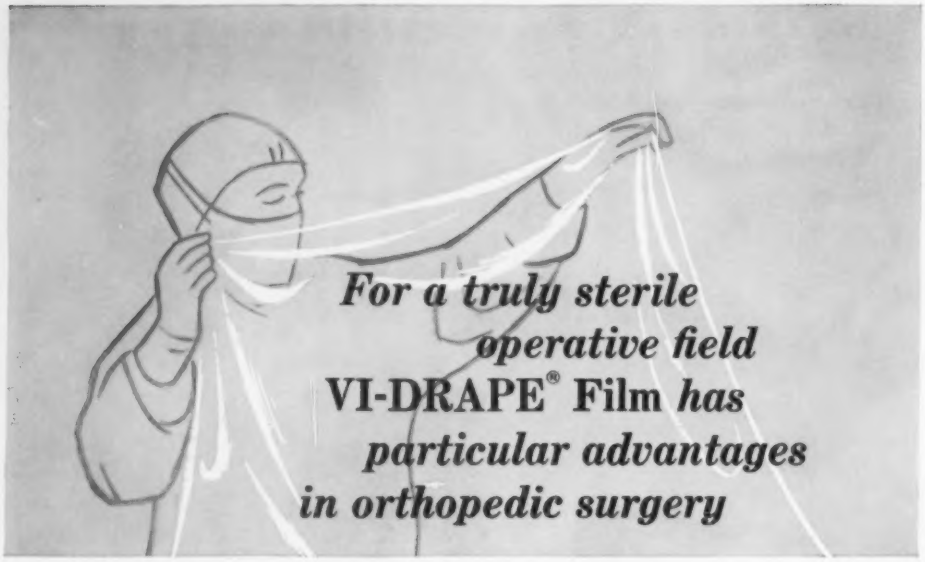

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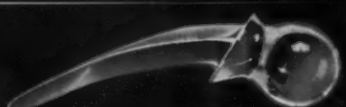

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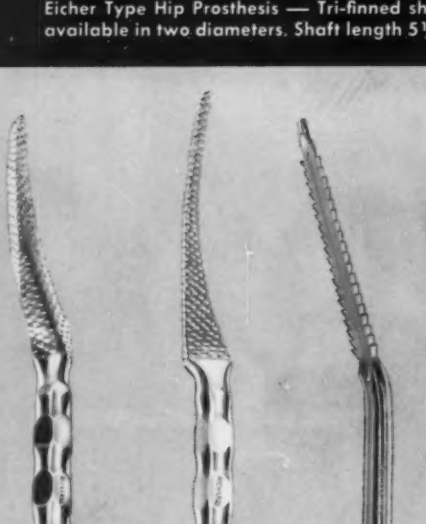

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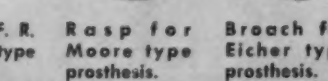

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VOLUME 42-A, NO. 3 APRIL 1960

The Journal of
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American Volume

Reconstruction of the Distal Part of the Thumb after Traumatic Amputation

Restoration of Function and Sensation Using Nerve, Tendon, and Bone from the Amputated Portion

BY CARL E. NEMETHI, M.D., LOS ANGELES, CALIFORNIA

The purpose of this paper is to present the case histories of six patients in whom a method of thumb reconstruction had been accomplished by utilizing the severed or remaining parts of the digit. Nerve grafts taken from the amputated thumb or the intact stripped digital nerve or nerves have been used to impart sensation to the enveloping pedicle graft.

Loss of the distal phalanx of the thumb by amputation or avulsion is so disabling that tedious reconstruction in several stages over a period of months has been considered worthwhile by some surgeons even if only an insensitive "post", capable of apposing the fingers, can be achieved. Many weeks are lost in waiting for the stump to heal before it can receive a secondary pedicle graft, and once the graft is attached more weeks must pass until the pedicle can be cut loose and prepared to receive the bone graft. Transplantation of bone from the ilium or ulna adds still another operation to the process. The end result is a numb projection that has no active motion and cannot sense cuts, burns, or bruises, with the result that destructive ulceration develops.

Sensation in a thumb appendage is so important to both function and survival that even pollicization of one of the fingers has been adopted, although it endangers a good finger by using it for transplantation to the stump of the thumb. Failure in such an attempt means loss of two digits, with further disability and deformity; success means, at best, a somewhat grotesque hand with limited function.

The method presented here makes the greatest possible use of amputated parts—bone, tendon, and nerve. General experience has shown that such structures, if properly nourished, are unusually resistant to destruction. Bone and tendon can be grafted even after cold storage. The concept of nerve-grafting is not new, its principle being that if nerve sheaths are anastomosed the axons in the proximal portion tend to grow distally. Since accidental amputation or avulsion may leave these durable structures relatively intact, even when the other soft tissues are badly crushed, salvage should be practicable in a high proportion of such injuries.

PROCEDURE

The following procedure for restoration of an amputated thumb has been developed and applied in six patients:

1. Shock is treated, usually by administration of a general anesthetic and intravenous infusion of saline solution.

2. The injured arm and the abdomen are scrubbed for ten minutes with antiseptic detergent.

3. The amputated portion of the thumb is cleaned similarly and wrapped in gauze sponge saturated with normal saline solution.

4. The thumb stump is debrided. Nerve trunk and tendon ends are identified, large vessels are ligated with plain 000000 catgut, and bleeding in the smaller vessels is controlled by clamping. The dry, raw stump is then covered with gauze.

5. An abdominal tubed flap graft is raised from either the right or left upper quadrant, depending on which thumb has been injured. If the right thumb has been injured, the abdominal pedicle is raised from the upper left quadrant, just below the rib cage (Fig. 1). The pedicle is usually started superior to the umbilicus

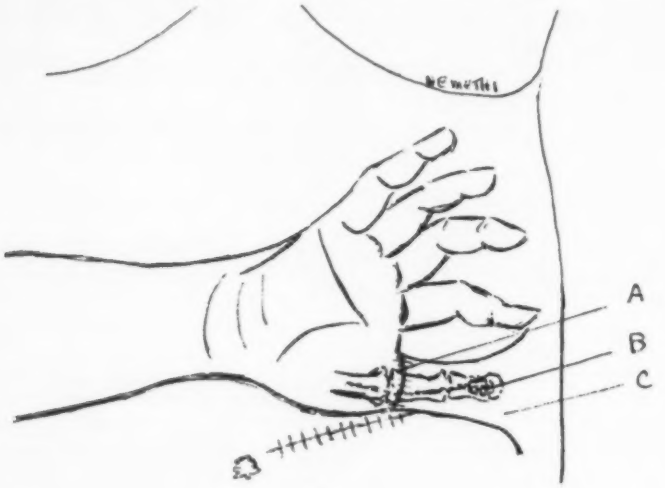

FIG. 1

Schematic drawing of an abdominal tubed flap graft raised from the upper left quadrant of the abdomen. The amputated right thumb has been reconstructed, the phalanges, tendons, and one nerve graft being enveloped by the pedicle. *A* shows the suture line joining the proximal viable soft tissues of the thumb to the distal edge of the pedicle. The base of the pedicle, *C*, is approximately from one and one-half to two times the width of the distal end. The dotted line, *B*, indicates the nerve graft and the location of the end-organ mass in relation to the distal phalanx and the pedicle graft. The hand and forearm are rotated upward to show the pedicle; ordinarily, the palm would be facing the abdomen and resting on fluffed kerlix. The abdominal incisions are closed in the manner indicated by the suture line.

and the skin incisions are carried outward to the lateral side of the abdomen so that the base is one and one-half to two times the width of the distal end (Fig. 1, *C*). The primary medial surgical incision passes through the skin, subcutaneous tissue, and superficial fascia, down to the deep fascia. After this initial incision has been made, the surgeon's finger is passed through this opening and used to separate the flap from the abdomen laterally by blunt dissection, following the fascial cleavage plane. This procedure eliminates much bleeding and oozing. After the undermining has been done, the two skin incisions outlining the flap are deepened into this plane. The unattached end of the flap is cut wide enough so that it can, without stretching, envelop the entire base of the thumb (Fig. 1, *A*). Further blunt dissection along the fascial plane further frees the skin and subcutaneous tissues superiorly and inferiorly to the surgical incisions so that these tissues can be approximated without tension to close the wound. If undermined enough, usually from four to five inches in either direction, closure can be accom-

plished without grafting skin from the thigh. Suturing the wound is done with interrupted mattress sutures of stainless-steel No. 32 wire. Closure is started at the mid-abdominal area and thence carried laterally. When this is completed, redundant fat is then removed from the flap with extreme caution so as not to interfere with or cut the blood supply at its base; interference with this blood supply will result in sloughing of the flap. One can shell out excessive fatty tissue by using minimum sharp dissection, thus avoiding division of the blood vessels. Hemostasis of the tissues must be meticulous and every small bleeding vessel clamped and tied with 000000 plain catgut. The flap, now having been prepared, is left for later use. The time interval of twenty to thirty minutes, during which salvageable material is being reconstructed into the so-called new thumb, permits the vascular pedicle flap to become stabilized and provides the opportunity to excise any distal tissues that become obviously cyanotic before final attachment of the pedicle to the thumb.

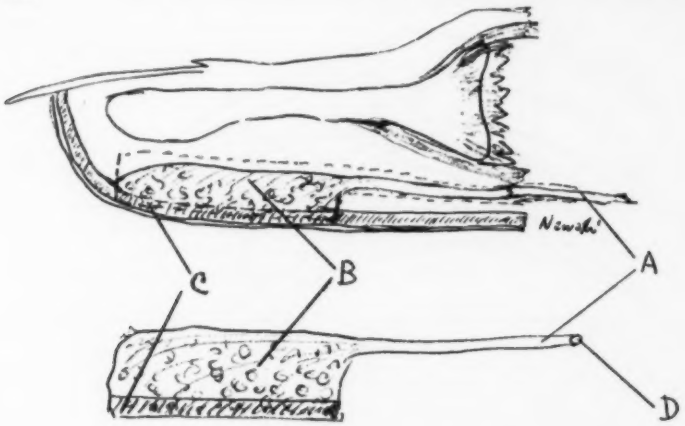

FIG. 2

Sketch of an amputated distal segment of the thumb. The course of the dissection followed from the proximal to the distal end of the digital nerve is indicated by the dotted line. The nerve trunk, *A*, is first freed, then the end-organ mass, *B*, and finally a strip of corium, *C*, are dissected out. The intact neurilemma, *D*, is identified by cutting off the proximal end of the nerve trunk, millimeter by millimeter, with a small sharp scissors until a clearly defined ring of neurilemma can be visualized.

6. The amputated portion of the thumb is dissected to salvage useful tissue. The amputated part may consist of the distal part of the thumb alone, cleanly cut (as by a knife or saw). More often, however, all of the soft tissues of the proximal phalangeal portion are stripped off and then amputated with the soft tissues and bone of the distal segment. At least one nerve trunk and its end organs are removed intact from the amputated portion (Fig. 2, *A*). This is best accomplished by identifying the proximal end of the severed or avulsed nerve trunk and dissecting it out from the soft tissues, proceeding distally. The trunk and its end organs are teased free from the enveloping soft tissues. The nerve terminals are found to be most abundant in the volar skin of the distal phalangeal portion. They consist of a fanlike mass of nerve branches and nerve endings (Fig. 2, *B*). Proceeding volarward with the dissection, the end organs are removed in a block of minimum-thickness corium, excluding the epidermis (Fig. 2, *C*). This is accomplished most readily by sharp dissection. When the nerve trunk with its branches and corium-encased end organs is completely dissected out, the nerve graft has the appearance of a long-stemmed bunch of grapes. The proximal end of the nerve is then sectioned, millimeter by millimeter, with a sharp scissors until a definite clean circular edge of neurilemma is present (Fig. 2, *D*). The proximal live nerve stump,

which has previously been exposed, is now similarly sectioned so that a corresponding circle of neurilemma can be identified. Should the nerve be intact, but traumatically stripped of its surrounding soft tissues, it is used as such. If it is attached to skin distally to avulsed soft tissue, the same dissection as that used for the amputated nerve and soft tissues is done. If no corium is attached, the branches and any end organs remaining are transplanted into the pedicle graft. Undamaged tendon is left attached to the bone. Finally, the remaining skin and soft tissues on the amputated portion are dissected from the phalanx, but the periosteum is preserved. The joint, if intact, is left with its investment of capsule, ligaments, extensor mechanism, and flexor tendon.

7. If the phalanges are fractured, they are immobilized by pinning with Kirschner wires. If the thumb is severed through a joint, the capsule and ligaments are approximated with buried 00000 surelen interrupted sutures. When the distal phalanx is lost as the result of a clean knife cut through the joint there usually remains sufficient capsule and attached ligaments to provide enough

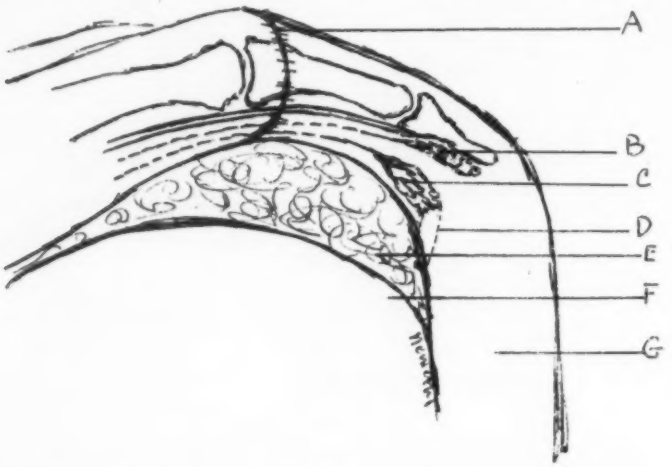

FIG. 3

Diagrammatic cross-section of the pedicle graft enveloping the bones, tendons, and nerves of the reconstructed thumb. The distal and proximal phalanges and part of the metacarpal are outlined. The suture line, approximating the distal raw surface of the pedicle to the proximal soft tissues of the thumb, is indicated by *A*. *B* shows one of the positions for the nerve graft where its end-organ mass rests on the periosteum of the volar surface of the distal phalanx; *C* shows the other, more sensitive position for the end-organ mass where it lies just below the deep surface of the pedicle skin at the point on the thumb which will contact the fingers during apposition. No. 000000 plain catgut fixation sutures, *D*, are shown passing from the end-organ mass through the pedicle skin to be knotted on the surface. Fluffed kerlix, *E*, separates the thumb, hand, fingers, and pedicle, *G*, from the abdomen, *F*.

substance for approximation and closure of the joint. In the majority of cases, however, one cannot hope to accomplish a complete anatomical reconstruction of the capsule and ligaments because there are, as a rule, only fragments of ligament and capsule left intact; nevertheless, apposition of these pieces with interrupted sutures does afford joint stability.

8. After stabilization and alignment of the phalanges, the tendon, if salvaged with the bone, is repaired with buried 00000 surelen sutures. If the distal portion of the tendon has not been salvaged, the proximal portion may be implanted in the proximal or distal phalanx. If the long flexor has been divided at the site of its insertion into the distal phalanx, a bone flap is raised and the tendon reattached to the phalanx by stainless-steel wire passed through drill holes under the

bone flap and tied on the dorsal surface of the phalanx. Should the long flexor tendon be severed, leaving only sufficient length proximally to reach the proximal phalanx, it is attached as far distally on this phalanx as possible. The distal joint of the thumb may then be fused.

9. If feasible, the corresponding proximal nerve trunk is mobilized and anastomosed end-to-end with the salvaged nerve trunk. This is done in the usual manner, approximating only neurilemma to neurilemma, with 000000 eye silk on an atraumatic needle. Six to eight sutures are placed, after first running the needle and silk through subcutaneous fat to facilitate easy slippage of the needle and suture material through the neurilemma. The severed ends are anatomically realigned. Injection of 0.1 to 0.2 cubic centimeter of normal saline solution with a very fine needle through the neurilemma at a point approximately 0.5 centimeter from the site of nerve suture will balloon the neurilemma at the suture line and demonstrate any large openings through which axons may later grow and form neuromata. Patency of the neurilemmal tube at the juncture is also demonstrated by this maneuver.

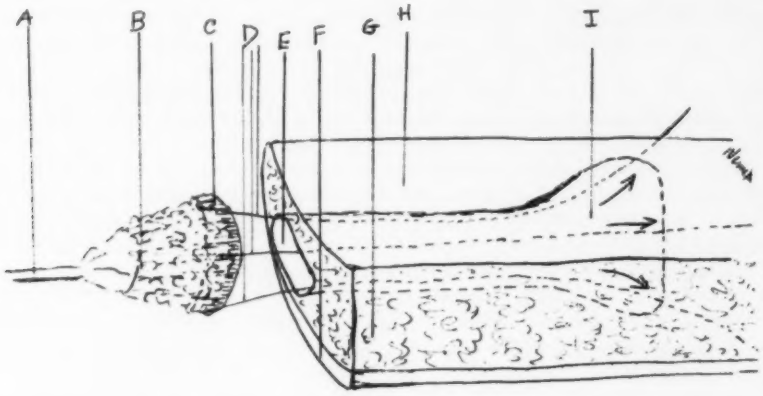

FIG. 4

Schematic drawing of a section of pedicle graft illustrating how the nerve graft is placed beneath the dermis. *A* is the nerve trunk, *B* the end-organ mass, and *C* the corium attached to the end organ. Three traction sutures of 000000 plain catgut, *D*, are attached to the mid-portion and lateral margins of the fanned-out end organs. The sutures pass through the distal edge of the corium on the end organ. With Bunnell needles these sutures are threaded along the tunnel, *E*, previously made through the subcutaneous fatty tissues, *G*, close to the skin, *F*, on the volar surface of the pedicle. The sutures are passed through the area, *I*, made to receive the end-organ mass and then out through the volar aspect of the pedicle skin to be tied on the surface. The arrows indicate the direction of traction. *H* represents the superficial fascia of the pedicle, the surface to come in contact with the reconstructed phalanges, tendons, and joints when the graft is sutured around them.

10. Two methods of nerve placement in the reconstructed thumb were attempted. In one method, the anastomosed nerve trunk, its branches, and end organs were fanned out over the volar surface of the distal phalanx and secured by fixing the end organs to the periosteal tissue with three tacking sutures of 000000 plain catgut (Fig. 3, *B*). In the other method the nerve was placed beneath the dermis of the pedicle graft (Fig. 3, *C*). This was done after the pedicle graft had been raised and rotated so that the portion of the graft which would become the volar surface of the thumb was identified. A mosquito forceps with a sharp nose was passed between the deep layer of the skin and subcutaneous fatty tissue to produce a passage from the proximal thumb distally to where the branches and end organs of the nerve were to terminate (Fig. 4, *E*, *F*, *G*, and *I*). A sharp, pointed scalpel was then passed through this tunnel, and, at the proposed site of fanning

out of the nerve endings, side-to-side dissection was carried out to clear an area for the end-organ mass (Fig. 4, *I*). One 000000 plain catgut suture was then placed through the tip and one through each side of the end-organ mass so that tension on these three sutures could fan out the branches of the nerve and its end organs. With the aid of Bunnell needles, the free ends of these three sutures were passed through the tunnel. The central one was brought out through the skin of the pedicle in the central and distal portion of the space previously fashioned for the end organs. The lateral ones were brought out about one centimeter to each side (Fig. 4, *D*). When traction was applied to the catgut sutures the end organs, branches, and nerve trunk were drawn through the tunnel, fanned out under the skin, and secured there by tying knots on the surface of the pedicle skin. During wound healing, these sutures were absorbed after the position of the relocated nerve was established. No infection resulted from this type of fixation.

11. With the proper placement and fixation of the grafted or salvaged stripped nerve in the pedicle, the reconstructed parts of the thumb will rest on the raw surface of the pedicle (Fig. 4, *H*). The distal edge of the pedicle is now sutured to the skin margin of the thumb stump by interrupted sutures of stainless-steel No. 38 wire. The starting suture is placed in the skin margins of the stump and the pedicle overlying the replanted digital nerve; interrupted sutures are then placed in the skin margins on each side of this suture so that the salvaged thumb tissues are encased by the pedicle (Fig. 3, *A*). The longitudinal suture line which closes the free end of the pedicle about the thumb is placed on the dorsum or the dorsolateral aspect. As closure approaches the origin of the pedicle from the abdomen, it may become apparent that formation of a tube here is not feasible since a tight tube in this area will constrict blood vessels and impair the blood supply. If these edges cannot be approximated loosely, they should not be approximated but left open and the raw surface covered by a split-skin graft taken from the thigh. The abdomen, wounds, and entire arm are painted liberally with tincture of benzoin compound. Fluffed kerlix is used to separate the arm from the abdomen (Fig. 3, *E*) and additional kerlix is placed around the pedicle graft and thumb so that the graft is relaxed and there is no undue pull or kinking, particularly at the base (Fig. 3, *G*). The ulnar nerve in the region of the elbow is well padded with fluffed kerlix. The arm is then secured to the abdomen and chest, using elastoplast reinforced with a scultetus binder. The fingers, pedicle, and reconstructed thumb are left free of bandages.

The patient is kept on the operating table during recovery from the anesthesia. By so doing the usual postoperative struggling can be controlled, avoiding immediate injury to the pedicle. As soon as the patient is coherent he is given antitetanus medication and antibiotics and is instructed in the mechanics of the graft. He is also given a small hand mirror which he can hold with his free hand in a position that will enable him to visualize the pedicle and its attachment to the thumb. He is then instructed to watch any kinking or change of color. By sharing part of the postoperative responsibility for successful graft healing, the patient conditions himself in ten to fourteen days so that only a few pieces of tape are necessary to hold bandages in place and immobilization is obtained by a sling. This permits the removal of the restraining tape and scultetus, allowing for freer active motion of all joints. A normal person does not injure the pedicle while sleeping. The freed arm, pedicle, abdomen, and hand are washed daily with septisol, and good hygiene, so important to all pedicle grafts, is maintained.

The patient is permitted to walk the first day after operation and encouraged to move his fingers, wrist, elbow, and shoulder as much as possible. With the freedom of motion afforded by this postoperative regimen, the patient is able to accomplish some shoulder motion and, in particular, to use the deltoid. The amount of wrist and finger motion possible is adequate to maintain function, but elbow motion is more restricted. Stiffness of all these joints has been largely overcome by this procedure, which avoids the three to four weeks of complete immo-

bilization required by other methods of postoperative care. It is interesting to note that patients instructed properly in the procedure advocated here have had no complaints about the lack of immobilization. None have torn their pedicles loose during sleep; in none have acute circulatory deficiency developed in the grafts. Three to four weeks after release of the pedicle, all patients regained a full range of active motion of the fingers, wrists, and elbows. Motion in the shoulder, particularly in abduction, has been more limited than in the other joints. The deltoid muscle has shown a mild degree of atrophy, but nowhere near the amount seen with complete immobilization of the shoulder. Older patients have had almost from 30 to 40 per cent more restriction of motion of the shoulder than the younger group. The treatment of choice for this restricted motion is active motion of the joints, although many patients have said that physiotherapy, in the form of whirlpool and massage, has aided them considerably.

Five of the six patients treated during the past two years by the general method just described had injury involving complete or virtual amputation of the thumb with separation of bone, tendons, and nerves. Adequate functional sensation returned in all five within two to four months after final transplant, usually occurring first over a small area of pedicle skin immediately overlying the transplanted nerve endings, then spreading distally and proximally over the skin on the volar surface. At first, coarse touch and pain were perceptible, followed later by light touch. After eight to ten months sensitivity to heat became established and lastly, gross stereognosis returned. Response to cold was much less accurate than to heat. One patient, Case 5, did not regain stereognosis, as did the others, but, nonetheless, the appendage was functional.

Sensation was much more acute in those patients who had stripped but intact nerves transplanted, as compared with those having a nerve graft.

With the establishment of functional sensation, normal cerebral and reflex control was regained, making the thumb efficient in holding objects lightly or firmly and in distinguishing surface textures. This control also was sufficient to protect the thumb from injury. The atrophy characteristic of denervated tissue did not develop; rather a conscious use of the thumb seemed to stimulate healing and vigor. Although no attempt was made at operation to provide a blood supply, tissue fluid in the pedicle seemed to provide adequate nutrition for primary healing. Good circulation developed later in all instances.

Patients who presented intact phalanges and joints invested by capsules and ligaments but with complete soft-tissue avulsion showed few bone changes at follow-up roentgenographic examination. Basically, some loss of joint space and bone density resulted from all of these injuries. Those injuries with complete disruption of the soft tissues and phalanges (amputation) showed roentgenographic changes similar to those seen in other types of bone grafts. One, however, demonstrated little change both roentgenographically and microscopically.

The interphalangeal joints developed early ankylosis or regained only minimum motion; the metacarpophalangeal joints were more mobile and useful but never attained a normal degree of motion. Motion of the carpometacarpal joint remained at a high level and aided materially in thumb apposition.

Repaired tendons and capsular and ligamentous tissues healed well, but with the usual connective-tissue proliferation and restriction of motion. Evidence of healing was demonstrated by functional return of the tendons and joints. In one patient (Fig. 10) there was visual evidence of healing of these structures. No histological sections were made.

No complications resulted from the use of primary abdominal tube flap grafts; they all healed well.

Although the reconstruction by no means resembled a normal thumb, the ease with which it can be used at least saves it from being conspicuous. To the patient it feels and functions like a thumb. In each case the patient has been able to resume work.

FIG. 5-A

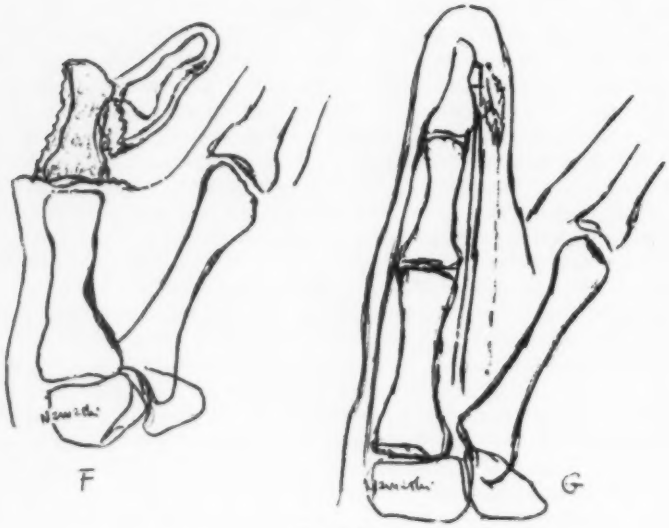

FIG. 5-B

Fig. 5-A: Case 1. The schematic drawing identifies the structures shown in the photograph. *A* is the avulsed and amputated distal portion of the thumb which includes the distal phalanx and soft tissues which covered the proximal phalanx. *B* is the severed flexor tendon; *C* the severed extensor tendon; *D* the distal articular surface of the proximal phalanx, and *E* the proximal phalanx denuded of skin and subcutaneous tissues.

Fig. 5-B: Illustration *F* shows the losses of bone and soft tissues resulting from the injury. *G* shows the reconstructed thumb, indicating restoration of the bones, tendons, and distal joint, and the location of the nerve graft (dotted line).

CASE REPORTS

CASE 1. L. P., a white, male machine operator, thirty-one years old, sustained an avulsion amputation of the right thumb on August 8, 1958, as a result of having it caught and fed between steel and rubber rollers. The soft tissues were avulsed in glovelike fashion from the proximal joint distally. Disarticulation occurred at the distal joint and all structures were severed—tendon, neurovascular bundles, and soft tissues (Fig. 5-A, *A* through *E*). The mangled thumb and distal phalanx were wrapped in a cloth at the plant, and the patient was sent to the hospital.

With the patient under general anesthesia, the proximal stump was debrided. A one-stage tube flap graft was raised from the upper left portion of the abdomen. The distal nerve trunk was dissected from the amputated thumb portion, including its end organs and a section of cutis (Fig. 6, *B* through *D*). The proximal end of the severed nerve trunk was sectioned cleanly and anastomosed to the proximal live nerve trunk (Fig. 7, *E*). The distal amputated phalanx was dissected from its soft tissues, leaving the periosteum and joint capsule attached to it (Figs. 7, *C* and 8, *A* and *C*). The distal capsular fragments were sutured to the proximal fragments. The long extensor and flexor tendons were reinserted under bone flaps on the dorsal and volar surfaces of the distal phalanx and fixed with sutures. The nerve endings were fanned out over the distal phalangeal periosteum and

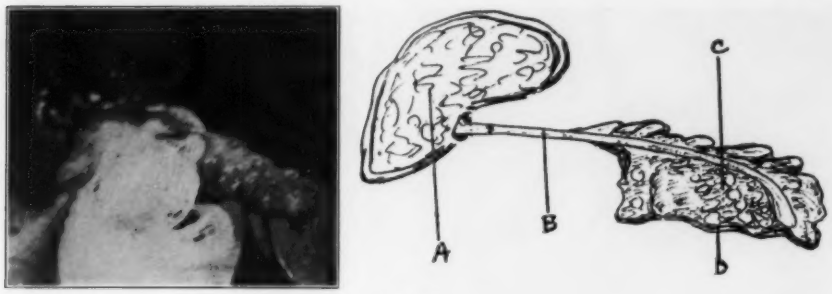

FIG. 6

Case 1. The photograph shows the nerve graft and end-organ mass; the schematic drawing identifies the structures shown. *A* is the debrided end of the stump of the thumb (proximal phalanx); *B*, the nerve trunk; *C*, the terminal nerve branches and end-organ mass; and *D*, the thin layer of corium attached to the end organ. The nerve graft is shown after it had been dissected from the soft tissues of the amputated portion and sutured to the stump of the remaining digital nerve.

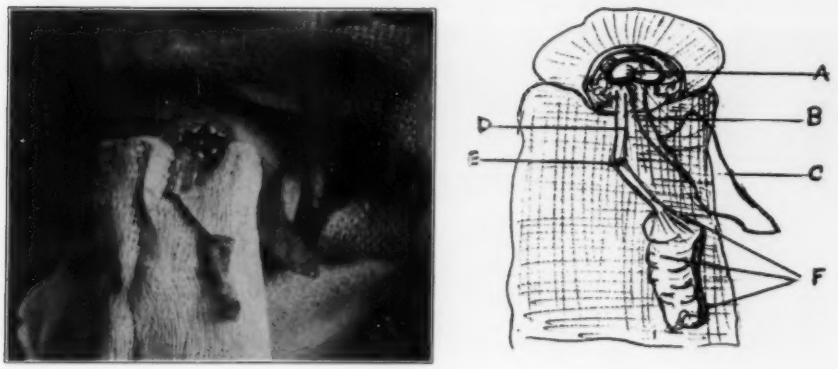

FIG. 7

Case 1. Photograph of the thumb during reconstructive procedure after suture of the nerve graft and reinsertion of the flexor tendon into the distal phalanx. The structures are identified in the sketch. *A* is the distal articular surface of the proximal phalanx (covered by gauze in the photograph); *B*, the flexor pollicis longus tendon reinserted into the distal phalanx *C*; *D*, the proximal nerve trunk projecting from the stump of the amputated thumb; *E*, the suture line joining the neurilemma of the nerve trunk and the nerve graft; and *F*, the nerve graft including the end-organ mass and attached corium.

FIG. 8

Case 1. The photograph and accompanying drawing show the distal phalanx *A*, from which all soft tissues have been removed except the periosteum and fragmented remains of the joint capsule and ligaments, *C*, which surround its articular surface, *B*. *D* is the distal articular surface of the proximal phalanx.

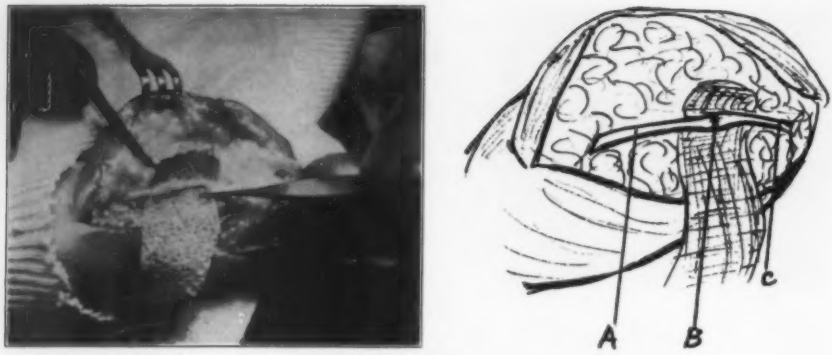

FIG. 9

Case. 1. Photograph and drawing of the nerve suture when the pedicle graft was revised three months after injury and primary reconstruction. *A* is the proximal nerve trunk; *B*, the site of nerve suture, showing the slight fusiform enlargement and the 000000 silk sutures in the neurilemma; and *C*, the distal nerve trunk, which is slightly smaller than the trunk proximal to the anastomosis. The surrounding tissues have a good blood supply and appear to be healthy.

FIG. 10

FIG. 11

Fig. 10: Case 1. Photograph made three months after injury and primary reconstruction of the thumb. The viable distal phalanx is shown as a white area, indicated by the hemostat. The thumb forceps are grasping highly vascularized tissue in intimate contact with the replaced distal phalanx. Blood vessels have penetrated into the bone. The pedicle skin and fatty tissue are superficial to these structures.

Fig. 11: Case 1. Reconstructed thumb two years after injury. The pinch mechanism is well established. The patient is able to pick up coins, nails, and other small objects without dropping them.

fixed with tacking sutures. All structures were then enveloped by the abdominal tube flap graft. The arm was fixed to the abdomen in the usual way. The patient was walking the day after operation and left the hospital one week later. Healing was by primary intention.

On September 19, 1958, the patient returned to the hospital and the graft was released from the abdomen. He left the hospital the following day. At that time he had good motion of the wrist, fingers, and elbow but complained of some shoulder pain. This was overcome within the next four to five days by active motion and deltoid message.

Roentgenograms made on September 23, 1958, showed that the reattached bone was essentially normal in appearance. The patient returned to work, using the injured hand moderately at this time.

The patient re-entered the hospital on October 29, 1958, for revision of the thumb pedicle (Fig. 10). At this time he could feel coarse touch, painful stimuli, and deep pressure on the thumb. The grafted nerve was exposed and found to be viable. The juncture site was well healed. No neuromata were present (Fig. 9, *A*, *B*, and *C*).

A biopsy specimen was obtained from the tuft of the distal phalanx. The histological section showed the cortical bone to be surrounded by dense collagenous connective tissue with no inflammatory reaction. The spaces between bone trabeculae were filled by fatty tissue containing few cells and occasional red cells. The bone was found to be viable. The bone matrix stained uniformly red, and most of the osteocytes in the lacunae were of normal appearance. The pedicle was shaped to

FIG. 12

FIG. 13

Fig. 12: Case 1. Photograph demonstrates the patient's ability to handle such objects as a pen or pencil. He can write well.

Fig. 13: Case 1. The "thumb" is versatile. Here, the patient exhibits an excellent grasp.

improve the appearance of the thumb. Healing occurred by primary intention and the patient returned to modified work in fifteen days. Sensation, which first appeared in a small circular area directly overlying the grafted end organs, gradually spread in a radiating fashion until it was present over the skin of the entire volar surface of the distal segment.

On December 15, 1958, the grip of the injured hand averaged twenty-eight kilograms; the uninjured, 105 kilograms. The reconstructed thumb extended 180 degrees at both joints. Flexion was 34 degrees at the metacarpophalangeal joint and 10 degrees at the interphalangeal joint. On May 21, 1959, the grip of the injured hand averaged 90 kilograms. Flexion of the proximal joint was 40 degrees; the distal, 15 degrees. The patient could readily differentiate hot and cold. Coarse stereognosis was present.

On December 8, 1959, follow-up roentgenograms showed normal bone in the phalanges. There was only very slight narrowing of the joint spaces. Sensation was present over the entire volar surface of the pedicle graft, particularly over the area of the fanned-out end organs. He could immediately feel pain, pressure, touch, hot and cold. He had stereognostic sense for such objects as a round and tapered pencil, a pin, a flat tongue blade, coins, and a blunt as opposed to a sharp edge. The patient returned to his regular job as machine operator. At the time of writing, he used his thumb for holding a knife or fork, writing, turning door knobs and small dials, wielding a paint brush, buttoning shirts, tying shoes, and other skills. He also demonstrated an excellent, strong pinch mechanism.

CASE 2. C. H., a white man, fifty-three years old, was injured on December 29, 1958. His right thumb was amputated when it was caught between a block and two rollers. The ulnar digital nerve was intact. Because the patient demanded that the amputated thumb be "sewn on", it was done. However, on January 12, 1959, gangrene with a line of demarcation was present and it was now evident to the patient that amputation of the partially gangrenous (dry) distal part of the thumb must be done. This was accomplished the following day. It was determined at surgery that the distal and most of the proximal phalanges were dead; the ulnar digital nerve and its end organs appeared to be viable. The nerve was dissected out from its surrounding necrotic soft tissues and was placed with its end organs under the live skin of the proximal stump (Fig. 14, *B*).

On January 30, 1959, the reflected nerve was dissected out from the healed stump, maintaining its proximal attachment. A tube flap graft was raised on the abdomen and the nerve was transplanted subdermally into the pedicle. The patient's progress was satisfactory, and on March 13, 1959, the pedicle was cut loose from the abdomen. The wounds healed well. Roentgenograms made on July 15, 1959, showed demineralization of the remaining proximal fragment of the proximal phalanx. On July 17, 1959, the now-healed thumb pedicle was re-entered and the degenerated fragment of the proximal phalanx was removed along with about one centimeter of the distal metacarpal, thus exposing the medullary canal. The transplanted nerve was exposed; it appeared to be healthy. It was traced distally and its branches and end organs were noted to be intimately attached to the overlying pedicle skin. An intramedullary iliac-bone graft was inserted into the metacarpal and the pedicle skin closed over it so that its volar aspect contained the nerve and end organs. The iliac-bone graft was about five centimeters long and 0.5 centimeter thick; at its widest it measured one centimeter. Advantage was taken of the normal curve of the crest of the ilium, using it to help bring the tip of the volar surface toward the index finger.

The postoperative course was uneventful and healing was by primary intention.

On December 7, 1959, the patient returned to full-time work. Because he was required to handle a knife, the thumb and index finger were constantly used as a pinching mechanism (Fig. 14, *C*).

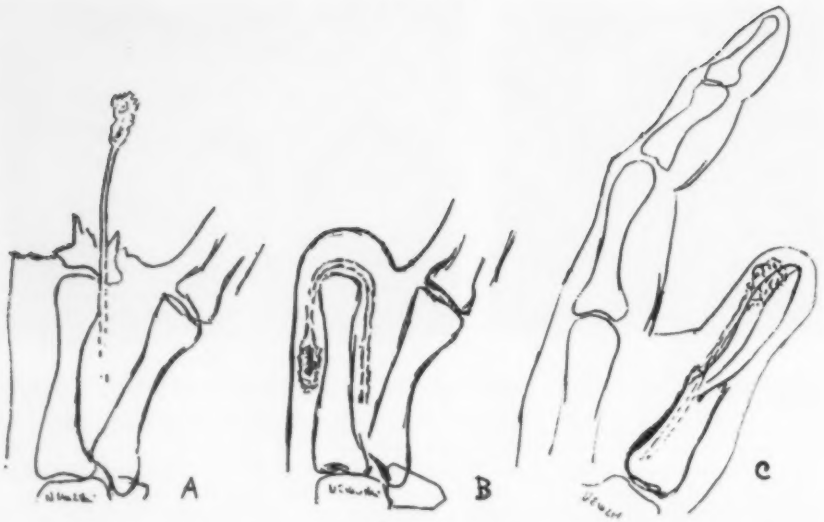

FIG. 14

Case 2. Line drawing showing the final amount of tissue loss resulting from the injury with one digital nerve, *A*, still intact. *B* demonstrates how the viable digital nerve was buried under the normal proximal skin so that it could be transplanted at a later date. Eighteen days after injury the nerve was dissected free and transplanted. It was noted at that time that its color and gross appearance differed little from that of a "normal" nerve. However, its diameter was about 15 per cent less than normal. *C* illustrates the reconstructed thumb after the pedicle graft had been revised and an intramedullary iliac-bone graft inserted six months after initial injury. At that time the transplanted nerve trunk and endings were seen to be fixed to the deep surface of the skin of the pedicle on the volar surface of the reconstructed thumb. At the last roentgenographic examination the bone graft appeared to be viable.

On March 13, 1959, before the graft was detached from the abdomen, the patient was able to determine coarse touch and pin prick over the area of the transplanted nerve and to distinguish this as "going up the hand", in contrast to pain experienced on the "abdominal side" of the graft. After detachment, this area was more sensitive than the corresponding area in those patients in whom the nerve was implanted on the periosteum. By December 1, 1959, temperature differentiation, particularly distinguishing heat, was well established. Cold could be determined, but with much less accuracy than heat. Stereognosis was developed well enough to distinguish coarse objects, such as a pencil or round or square objects, but finer differentiations were lacking. No further revision of the reconstructed digit was done.

Since this patient is of the older-age group, he experienced shoulder stiffness and pain two to three weeks after release of immobilization. However, he responded well to exercise and massage of the deltoid area. He also had some restriction of motion of the interphalangeal joints as a result of failing to exercise the fingers as directed while the arm was immobilized. At the last examination (December 1, 1959) he had a full range of motion of the shoulder, wrist, elbow, and fingers. In the thumb there was a useful range of motion at the carpometacarpal joint—the only joint remaining in this digit. The injured hand had an excellent pinch mechanism and a grip of sixty kilograms, compared with a grip of ninety kilograms in the uninjured hand. The patient could pick up coins, hold a knife and fork, button his shirt, tie shoe laces, and grasp and pull out paper stock. He had been able to work on a ladder, breaking plaster from walls and ceiling with a ten-pound sledge hammer.

CASE 3. V. S., a white, male machine operator, fifty years old, caught his left thumb between two rollers on August 27, 1958. This crushing injury caused almost complete amputation through the distal joint and open fractures of the two phalanges. The digital nerves were crushed but intact (Fig. 15, *A*). Because the patient had heard of fingers being "sewed on" he insisted that these crushed tissues be reattached despite the surgeon's advice to have an immediate pedicle graft. The distal phalanx and the fractures were stabilized by Kirschner wires drilled into the stable portion of the proximal phalanx, and the soft tissues were approximated with stainless-steel wire.

The patient left the hospital five days later. The reattached soft tissues, which were dusky in color at that time, became necrotic. A roentgenogram made on September 16, 1958, disclosed osteomyelitic destructive changes in the fractured and partially amputated phalanges. Therefore, on September 18, 1958, the patient was readmitted to the hospital and all necrotic tissue was

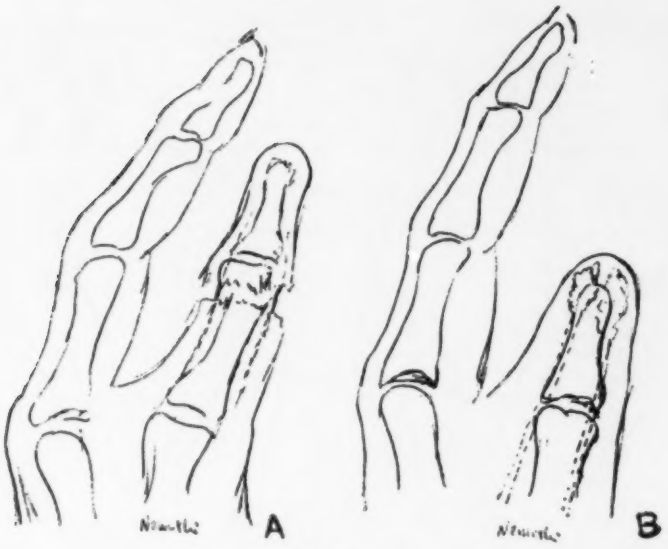

FIG. 15

Case 3. Schematic drawing showing the extent of the injury, *A*, and the final result, *B*. At the insistence of the patient an attempt was made to save the crushed and amputated portion, but gangrene ensued. When the gangrenous tissue was removed three weeks after injury, the nerves appeared to be viable and were preserved, the stump being covered with a pedicle flap. Osteomyelitis followed, which necessitated sequestrectomy and later revision of the pedicle with the result shown in *B*. Although the thumb is short, the relatively normal sensation (coarse pain, pressure, temperature, and stereognosis) resulting from preservation of the nerves rendered the function of this finger adequate, even though pinch was poor because of the short thumb.

excised from the thumb. Since the digital nerves were still viable, they and their end organs, including a small amount of cutis, were dissected free. A portion of the distal phalanx appeared viable after removal of surrounding soft tissues. This was pinned to the remaining living portion of the proximal phalanx. Because the tendons were obviously devitalized, they were excised. The nerves were fanned out over the pinned phalanx in the usual manner and all structures were encased in a one-stage abdominal tube flap graft.

The patient was walking the day after surgery, and left the hospital ten days later. He moved all joints as instructed. The pedicle healed but there was some slight but persistent drainage. On November 6, 1958, the patient re-entered the hospital. The pedicle was released and the patient was sent home two days later. The abdominal wound healed, but the distal end of the pedicle became erythematous and began to have a slight, cloudy serous drainage. The patient complained of a painful thumb. Roentgenograms made on November 18, 1958, demonstrated bone necrosis and sequestration of the distal phalanx. Two days later a sinus developed. The pin and sequestrated portion of the distal phalanx were removed through the sinus tract. After this, drainage and pain subsided and the tract closed spontaneously. On April 5, 1959, after adequate shrinkage of the pedicle graft had occurred, the redundant fatty tissue was excised and the pedicle was shaped. The nerves were found to be viable at this procedure.

The remaining three-fourths of the proximal phalanx was viable and strong (Fig. 15, *B*). Flexion of the metacarpophalangeal joint was 30 degrees on this side and 45 degrees in the normal thumb. Extension was 170 degrees in the injured thumb and 180 degrees in the uninjured. Sensations of coarse pain, pressure, and temperature, and stereognosis were established. Motions of the fingers, wrist, elbow, and shoulder were normal. Shoulder pain persisted for ten days after release of immobilization. At the time of writing, the patient uses the thumb for eating, bathing, and working as a machine operator. He can pick up coins and turn door knobs. Since function is adequate, no further surgery is indicated.

Case 4. C. S., a carpenter, twenty-eight years old, sawed through the proximal phalanx of his right thumb with a power saw. The distal part of the thumb was attached to the proximal portion by a small bridge of dorsal skin and tendon. The entire thumb was immediately wrapped in a bandage and the patient sent to the hospital, arriving two hours later.

Examination disclosed a clean cut that had severed the long flexor tendon, both neurovascular bundles, and the bone, but had left the extensors intact (Fig. 16, *A*). The thumb distal to the

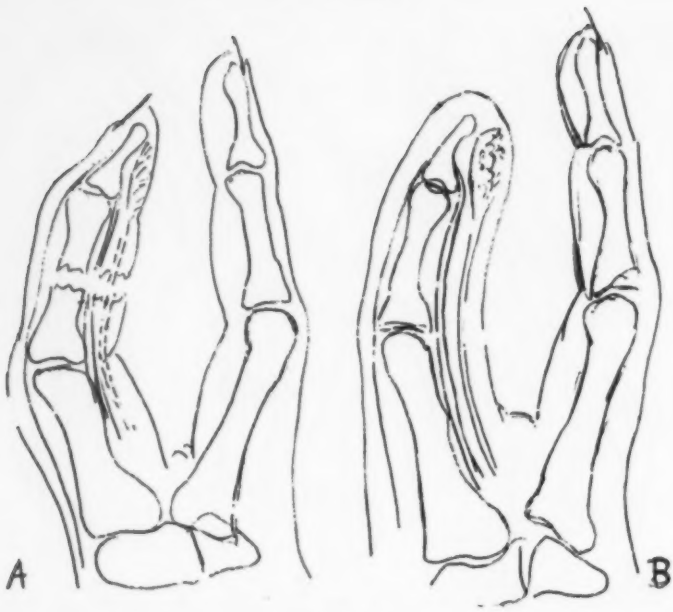

FIG. 16

Case 4. Schematic drawing showing the initial injury *A*, and the final result, one year later, *B*. A dorsal longitudinal strip of skin, soft tissues, and extensor tendon survived the immediate trauma. The abdominal pedicle was sutured longitudinally to this flap rather than by the usual method of a circular anastomosis. This preserved the added blood supply made available by this dorsal tissue. It was noted that fracture healing and the restoration of bone viability were accelerated in this thumb, presumably because of the added vascularity here, compared with the thumbs which depended entirely on the pedicle for nourishment.

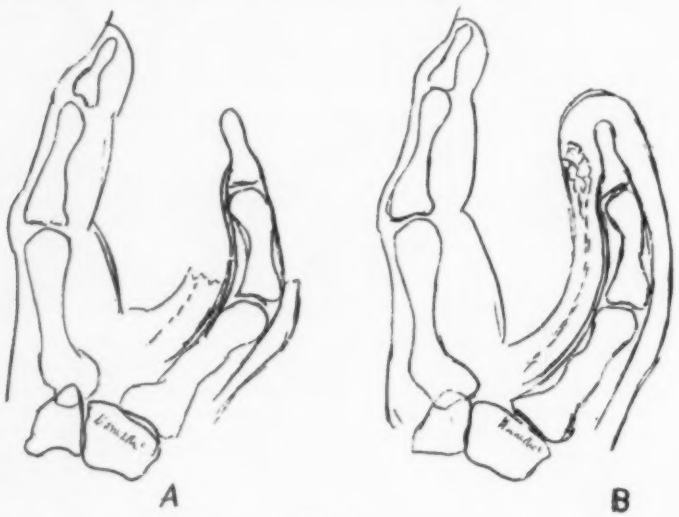

FIG. 17

Case 5. Line drawings showing the original injury, *A*, with complete loss of the skin and subcutaneous tissues covering the phalanges, and the final result, *B*, after transplantation of a digital nerve and end organ into the skin of the abdominal pedicle used to cover the thumb. The dotted line indicates the location of the transplanted nerve. Normal length, a useful range of motion, and sensation adequate for good function were restored to this thumb.

wound was cyanotic and, obviously, would not survive. This was explained to the patient, and permission was granted for reconstructive surgery.

With the patient under general anesthesia and with the usual preoperative preparation, a tube flap was raised. The devascularized volar soft tissues were dissected from the phalanges. The vascularized dorsal integument was left intact. The fractured phalanx was stabilized by Kirschner wires, the flexor tendon was repaired, the best preserved distal nerve trunk and endings were anastomosed to the least damaged proximal trunk, and the entire structure was enveloped by the tube pedicle.

The patient was walking the day after surgery and left the hospital ten days later. He was then treated as an ambulatory patient. On the twelfth postoperative day immobilization of the arm and pedicle was reduced to just a sling. The abdomen, pedicle, and arm were washed with septisol every two to three days to maintain good hygiene.

Healing was by primary intention, and in five weeks the pedicle was detached. Coarse pressure and pain became established on the volar skin of the pedicle in ten weeks. The injured man returned to light work after twelve weeks. Roentgenograms made four months after injury demonstrated some bone demineralization, but the fracture had healed in good position. Active flexion at that time was 15 degrees in the metacarpophalangeal and 5 degrees in the interphalangeal joint.

Six months after the injury the pedicle was defatted and shaped, meticulously avoiding the live nerve graft and endings. The Kirschner wires were removed at that time.

After one year the patient could feel pressure and pain well and had some gross stereognosis (Fig. 16, *B*). The grip of the injured hand averaged 105 kilograms; that of the uninjured hand, 160 kilograms. Motion of the proximal joint had improved to 30 degrees of flexion, but the distal joint remained at 5 degrees. Extension was 180 degrees in both joints. At this time the patient was able to resume his job as a carpenter but had some understandable difficulty in picking up nails and using a power saw. He was able to write, use silverware, pick up coins, button his clothes, tie his shoes, tell the difference between hot and cold and flat or round objects, but lacked two-point discrimination.

Case 5. E. S., a white machine operator, forty-five years old, caught his left thumb between two rubber rollers. A glovetype avulsion of all soft tissues took place. The thumb and damaged tissues were bandaged, and the patient was sent directly to the hospital.

At surgery, with the patient under general anesthesia, it was determined that the avulsion of the soft tissues started at the proximal third of the proximal phalanx and included both neurovascular bundles, leaving the tendons and distal phalanx stripped bare with the distal joint intact (Fig. 17, *A*).

A one-stage tube pedicle was raised on the upper right portion of the abdomen. The proximal soft tissues were debrided, and the nerves and their endings were dissected from the avulsed soft tissues. Anastomosis of the best nerve graft to the best proximal nerve trunk was performed. This nerve graft was then placed subdermally in the pedicle.

Immobilization and follow-up care were as usual. The patient walked the day after operation and left the hospital twelve days later. There was moderate serous drainage from the base of the pedicle at the site where the abdominal deficit had been closed, but no evidence of infection was present. The pedicle was released in six weeks.

Gross pain and pressure sensation were established in twelve weeks, and in sixteen weeks light touch could be distinguished. Flexion of the proximal joint was 32 degrees; of the distal, 15 degrees. Extension of all joints was 180 degrees. Roentgenograms disclosed no marked bone changes. Joint spaces were slightly narrowed. The grip of the injured hand was 40 kilograms; of the uninjured hand, 165 kilograms. The patient was engaged in moderate work. He could open doors, drive his car, pick up small objects, and help guide stock with the uninjured hand.

At the end of six months, when maximum shrinkage of the pedicle had occurred, the graft was revised. At fourteen months the patient returned to the same job he held before the injury. Stereognosis was lacking, but pain and pressure sensation were well developed on the volar surface of the pedicle skin. Motion of the distal joint had diminished to a bare 5 degrees. The grip on the injured side averaged eighty-five kilograms. The patient felt that he had a good, functional appendage that enabled him to continue making a living (Fig. 17, *B*).

Case 6. C. S., a white, male paper-machine operator, sixty years old, caught his left thumb between rubber rollers. Before the machine could be stopped all the skin, the nail, and the subcutaneous tissues were stripped from the digit.

The patient was hospitalized one hour later and immediately taken to surgery. There was complete loss of integument from the proximal third of the proximal phalanx to the tuft of the distal phalanx. The tendons were intact but there were multiple contusions and the tendon surfaces were roughened as by sandpaper, instead of presenting the normal smooth, glistening appearance. The distal joint demonstrated a full range of passive motion and no gross tears of the capsule or ligaments were noted. The ulnar digital nerve was stripped clean of its accompanying vascular bundle and all soft tissues. The nerve sheath was intact. The terminal branches and end organs were still attached to a small amount of subcutaneous tissues. The radial digital nerve was absent (Fig. 18, *A*).

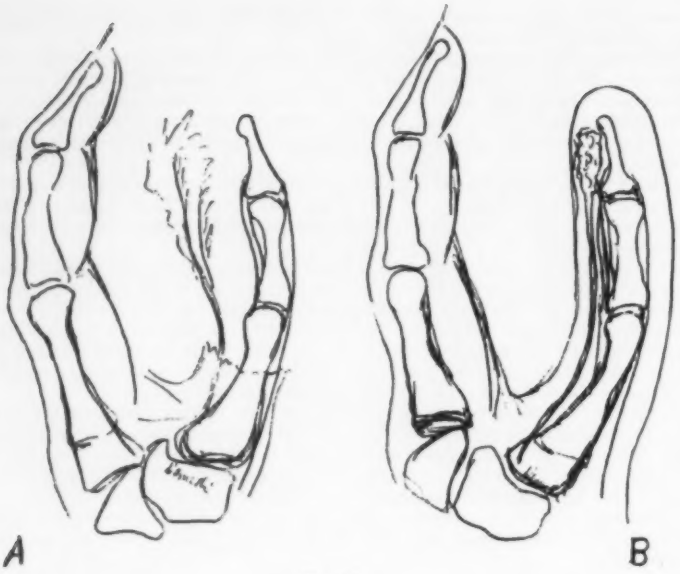

FIG. 18

Case 6. *A* shows the extent of the soft-tissue loss, which included complete loss of the integument. The tendons and joint capsules were intact but contused. The ulnar digital nerve remained stripped of all surrounding tissue except for a small amount of subcutaneous tissue attached to its end organs.

B portrays the final result, approximately one year after injury. Treatment was by a primary one-stage pedicle graft, and revision and defatting of the graft four and one-half months later. At the secondary procedure the graft was defatted, particularly over the end-organ mass at the contact surface of the finger, to increase sensitivity.

A one-stage tube flap graft was raised from the upper right part of the abdomen. The subcutaneous tissue attached to the nerve end organs was trimmed, and the end organ attached to the periosteum of the distal phalanx. The phalanges, tendons, and transplanted nerve were then enclosed in the pedicle graft and the arm was secured as described previously.

The patient left the hospital in ten days, after an uneventful recovery. Eight weeks later the pedicle was released; it had healed by primary intention in fourteen days. At the end of ten weeks the patient was tested for sensation; he said he could only detect deep pressure "on the bone". There was no sensation on the distal volar surface of the pedicle skin. The patient could use the reconstructed digit well to pick up large objects, to open doors, to eat, and to drive a car, but complained of lacking "feeling" and "dropping things".

The pedicle was large, and after another eight weeks it was decided to revise the bulky appendage.

Revision was carried through the original surgical scars with care to avoid the position of the transplanted nerve. The nerve was exposed and the trunk and end organs dissected free. The trunk was shiny and appeared grossly to be viable, as did the end-organ mass. Further revision and defatting of the pedicle was carried out and the apposing surface of the thumb-pedicle skin determined. At this site, defatting was carried out to the deep surface of the skin and an area cleared to accommodate the nerve-end mass which was fanned out and secured by three 000000 plain catgut sutures to the edges of the surrounding subcutaneous tissues. The location of the end-organ mass was carefully placed on the side of the pedicle skin which subsequently would contact the index finger and the revised flaps were closed with interrupted stainless-steel wires.

Four days later the bandages were removed at the office; the revised pedicle was observed to be healing nicely. At this time the patient was tested for sensation. He again could feel deep "bone pressure". Sensation in the pedicle skin was lacking, with the exception of one area approximately one centimeter in diameter, which corresponded exactly to the area of skin overlying the transplanted end-organ mass. Here the patient could detect painful "skin" stimuli, such as light pressure with a sharp-edged instrument, and differentiate it from the deep "bone pressure."

No further revision was necessary. The patient returned to his regular job as machine operator three weeks after the last revision.

One year later the graft showed no evidence of ulceration or atrophic skin changes (Fig. 18,

B). Sensation of the volar overlying skin to the end-organ mass was acute for pain, pressure, touch, hot and cold, and there was a stereognostic sense for such objects as a round pencil, a sharp or dull pointed instrument, and a flat object as opposed to a round one. The pinch mechanism was well established. Grasp of the uninjured hand averaged eighty kilograms; that of the injured (dominant) hand, seventy-two kilograms. The patient said that he might be able to grasp harder but the instrument hurt the "thumb".

Flexion of the injured distal joint was 12 degrees and the proximal was 28 degrees. Extension of the distal joint was to 170 degrees and of the proximal 180 degrees. Flexion of the distal joint of the uninjured thumb was 78 degrees and of the proximal joint 58 degrees. Extension was to 180 degrees in both joints.

SUMMARY

Six cases have been presented to demonstrate a method of thumb reconstruction whereby an amputated or avulsed portion of the thumb may be reconstructed, using the bone, tendons, and nerves from the amputated portion. The amputated bone can be pinned in place with its tendon intact or if the tendon is severed it can be reimplanted in the distal phalanx or attached to the proximal phalanx if the tendon is too short. A nerve trunk with its end organs can be reanastomosed to one of the proximal trunks of the digital nerves. An intact nerve from which the surrounding tissues have been stripped can be transplanted into proximal viable soft tissue for later use or it can be transplanted immediately into a pedicle graft. The reconstructed bones, joints, tendons, and nerves can be covered with an abdominopedicle graft at the same operation.

CONCLUSION

The operation herein presented:

1. Reduces thumb reconstruction to a single-stage procedure except for freeing the pedicle graft and, in some cases, bone-grafting and revision to improve the appearance of the thumb;
2. Eliminates, in most cases, the need for taking an iliac-bone graft;
3. Imparts sensation to the reconstructed portion;
4. Provides a more viable and functional thumb than is produced by other methods of reconstruction.

Spondylosis of the Cervical Spine with Compression of the Spinal Cord and Nerve Roots

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Hypertrophic changes in the cervical vertebrae are common findings in middle and old age but only in comparatively few patients do they produce compression of the spinal cord or nerve roots, or both. When compression does occur, the symptoms frequently simulate degenerative diseases of the spinal cord, such as primary lateral sclerosis, multiple sclerosis, and amyotrophic lateral sclerosis.

The hypertrophic changes affect all parts of the involved vertebrae, producing not only osteophytic ridges across the ventral wall of the spinal canal, but also deformed intervertebral foramina, enlarged pedicles, and thickened laminal arches. As a result, the spinal cord may be compressed from different directions rather than just on its ventral aspect by osteophytic ridges. At times, differential compression of the nerve roots may occur, only one component of the root, either motor or sensory, being affected. If only the motor nerves are involved in combination with compression of the spinal cord, the presenting symptoms may closely resemble amyotrophic lateral sclerosis.

The neurological symptoms in cervical spondylosis seem to vary with the bone changes. The spinal cord may be compressed by a cartilaginous ridge (a precursor of an osteophyte), by an exostosis in the region of an old compressed fracture, by hypertrophic changes in the pedicles or laminal arches, or by traction from the dentate ligaments as a result of displacement of the spinal cord [12].

It is the purpose of this communication to discuss the mechanisms which produce compression of the spinal cord and nerve roots in spondylosis of the cervical spine with particular reference to the differential compression of the nerve roots that is sometimes observed. This discussion is based on a study of twenty patients treated surgically for this condition, on anatomical studies of cadavera, and on roentgenological examinations of the cervical spine.

ANALYSIS OF CASES

Nineteen of the twenty patients were male and one was female. The youngest was thirty-nine, and the oldest was seventy-two years of age (Table I).

The duration of symptoms prior to surgery varied from one to twelve years. Only four of these patients had had symptoms for less than one year—eight, five, four, and one month, respectively. In all patients the course was progressive, usually with a gradual increase in the severity of symptoms.

Eight patients presented a definite history of trauma that had either initiated or aggravated their clinical symptoms. The symptoms and signs developed after a so-called whiplash injury in five patients; after a somersault in one patient; and after a stumble over a railway track in another patient. One patient fractured the spinous process of the fourth cervical vertebra when diving, but symptoms of compression of his nerve roots did not develop until twenty-six years later. In this patient, the hypertrophic spondylosis was found at the level of the old fracture (Case 14).

Pain was a prominent symptom in thirteen patients. Four patients complained of a vague dull ache between the shoulder blades; nine patients had a sharp radiating pain characteristic of nerve-root involvement; and three patients had dull pain involving the shoulder and arm. The pain usually was referred to two

TABLE I

SUMMARY OF HISTORY AND FINDINGS

Case	Sex	Age	Duration of Symptoms (*Years*)	History of Trauma	Signs of Cord Compression	Type of Involvement (Sensory or Motor Nerve Root, or Both)	Sensory Level on Trunk	Bladder Involvement	Manometric Findings of the Cerebrospinal Fluid According to Position of Neck	Total Protein of Cerebrospinal Fluid (*Milligrams*)
1	M	52	1/12	Yes	Yes	Sensory	None	No	Normal	41.85
2	M	67	5	Yes	Yes	Both	T2	No	Block in hyperextension	70
3	M	72	1	No	Yes	Both	T7	No	Block in hyperextension	100
4	M	44	12	No	Yes	Motor	T4	Yes	Block in extension, and partial block in neutral	207
5	M	54	8/12	No	No	Both	None	No	Partial block in hyperextension	58
6	M	66	2	No	No	Sensory	None	No	Partial block in hyperextension	116
7	M	55	1	Yes	Yes	Both	T5	Yes	Normal	31
8	M	39	1/12	Yes	No	Both	None	No	Partial block in hyperextension	60
9	M	48	4	Yes	No	Both	None	No	Partial block in hyperextension	67.40
10	M	48	1	No	Yes	Motor	T5	Yes	Partial block in neutral, and block in extension	108
11	M	53	6	No	Yes	Motor	T4	Yes	Block in extension	106
12	F	63	2	No	No	Sensory	None	No	Normal	51.20
13	M	58	1	Yes	Yes	Both	None	No	Partial block in extension	46.50
14	M	48	5/12	Yes	Yes	Both	T4	No	Partial block in extension	60.45
15	M	42	1	Yes	No	Both	None	No	Normal	56
16	M	57	2	No	Yes	Motor	None	Yes	Block in extension	85
17	M	62	1	No	Yes	Motor	None	No	Normal	37
18	M	45	2	No	No	Both	None	No	Normal	56
19	M	62	1	No	Yes	Both	T6	No	Partial block in hyperextension	63
20	M	62	1 1/2	No	Yes	Both	T7	No	Partial block in hyperextension	80

different locations: along the distribution of the affected cervical nerves; and in the thoracic region. Seven patients had thoracic pain; in five it was bilateral, and in two it was unilateral. In the latter two patients the pain was localized in the precordial area and resembled cardiac pain. Pain was absent in three patients.

Unilateral cranial pain of a throbbing nature appearing in bouts was noted by six patients. The pain was referred to the region behind the ear, to the ipsilateral eye, and to the side of the face and neck.

Dysesthesia in the involved arm, hand, and fingers was noted by ten patients Four patients complained of coldness in both legs and both feet. Two patients described a feeling of constriction or compression around the mid-thoracic area. One patient noticed an unbearable itching associated with tingling in the sacral and perianal region and in the rectum. Two patients described a tingling or a sensation like an electrical shock passing along the spine whenever the neck was hyperextended.

A level of hypalgesia was demonstrated in the thoracic region in nine patients. In three patients who had no pain, a vague and inconsistent sensory level was found, which shifted from the fourth to the sixth thoracic vertebra at different times of examination. Fifteen patients had hypalgesia along the distribution of the cervical nerve roots. Temperature and vibration senses were impaired in four patients, and position sensation was not appreciated in one patient.

Three patients were partially paraplegic, and one was quadriplegic. Four patients had unsteady gaits. Three patients had signs resembling a Brown-Séquard syndrome. A subjective feeling of fatigue in the lower limbs was noted in three patients, but without demonstrable weakness. Various degrees of paralysis of the lower-motor-neuron type were found in the upper extremities of fifteen patients —four patients with bilateral and eleven with unilateral involvement. Fasciculations in the muscles of the shoulder girdle and upper arm were observed in eight patients—bilateral in two patients and unilateral in six.

Seven patients experienced frequent cramps in the lower limbs, and six patients had spasticity—one having it in all four limbs, three in the lower, and two in both the upper and lower limbs of one side.

Eight patients had ataxia of the trunk, and eight had ataxia in the lower extremities.

Deep-tendon reflexes were hyperactive in thirteen patients. Hyperreflexia in the upper limbs associated with muscular atrophy was observed in five patients. Areflexia was noted in the upper limbs in four patients. Absence of the ankle and knee jerks in both lower limbs was found in one patient with hyperreflexia of the left upper extremity and spastic paraparesis. This patient had a history of tabes dorsalis that had been treated twenty years before.

A pathological reflex was found in one or more limbs in eleven patients, including four who had sustained patellar and ankle clonus.

A hypotonic bladder was demonstrated by cystometric study in three patients, and an atonic bladder was demonstrated in two patients. Sexual impotence was stated in the history of two patients.

Limitation of neck movement was noted in four patients. In two of these, deviation of the neck to one side was limited because of pain, and in the other two hyperextension was guarded because a marked dysesthesia passed down their spines when this motion was attempted.

Manometry of the cerebrospinal fluid showed a partial or complete block when the neck was hyperextended in fourteen patients. Partial block in the neutral position [14] of the neck was noted in two patients. The total protein content of the cerebrospinal fluid was increased in fifteen patients and normal in five. The highest reading of the total protein content was 207 milligrams per 100 milliliters.

Roentgenograms of the cervical spine showed a reversal or straightening of the normal curvature in nine patients. A narrowed intervertebral space was conspicuous in four patients, and constriction of the intervertebral foramina was

TABLE II

SUMMARY AND RESULT

Case	Site of Laminectomy	Site of Foraminotomy	Site of Excision of Arachnoid Membrane	Site of Section of Dentate Ligament	Removal of Bone Ridge	Functional Improvement *†**	Symptomatic Relief ††	Remark
1	C4-C7			C4-C7		Partial	Partial	
2	C3-C7	C3-4, bilateral	C3-C6	C2-C7		Satisfactory	Satisfactory	
3	C3-C6	C3-4, bilateral	C3-C6	C3-C6		Partial *	Partial *	
4	C4-C7	C4-5, C5-6, bilateral	C4-C6	C4-C7		Partial	Partial	
5	C6-C7	C6-7, right				Partial *	Partial *	
6	C4-C7	C5-6, C6-7, right	C4-C6	C4-C7		None *	None *	
7	C3-T1	C5-6, C6-7 C7-T1, right	C4-C7	C3-C7		Partial	Satisfactory	
8	C3-C5	C3-4, C4-5, left	C3-C5	C3-C5		Satisfactory	Satisfactory	
9	C4-C7	C5-6, right	C4-C7	C4-C7		Satisfactory	Partial	
10	C4-C7		C4-C7	C4-C7		Partial	Satisfactory	
11	C3-C7			C3-C7		**	**	Died
12	C5-C6	C5-6, left		C5-C7	Partial, C5-6		Partial	
13	C5-C7	C5-6, C6-7, left C5-6, right	C5-C7			Satisfactory	Satisfactory	
14	C4-C7	C4-5, right	C4-C7	C4-C7		Satisfactory	Satisfactory	
15	C3-C6	C4-5, C5-6, left		C3-C6		Satisfactory	Satisfactory	
16	C4-C7	C5-6, bilateral	C4-C7	C4-C7		None	None	
17	C5-C7	C5-6, C6-7, right C5-6, left	C5-C6	C4-C7		None	Partial	
18	C4-C6	C4-5, left	C4-C6	C4-C6		Satisfactory	Satisfactory	
19	C5-C7			C5-C7		None *	None *	
20	C5-T1		C5-T1	C5-T1		Partial	Partial	

* The follow-up period was less than one year and the result was not evaluated.
** The patient died from myocardial infarction one month after surgery.
† Functional improvement: "partial" indicates the patient returned to work for part time or changed to an easier job, the patient being left with appreciable neurological deficits. "Satisfactory" indicates the patient returned to the original job, although more or less severe neurological deficits were still demonstrable.
†† Symptomatic relief: "Partial" indicates partial relief of pain or of dysesthesia and the need for narcotics, infrequently, for relief of pain; "satisfactory" indicates complete relief of pain or dysesthesia, or both.

seen in eleven. Evidence of hypertrophic spondylosis with anterior osteophytic ridges was found in sixteen patients. In four patients the myelographic defects were produced by cartilaginous ridges which were later found at surgery. In all twenty patients more than one interspace was affected. The interspaces involved in these patients were distributed between the third cervical and the first thoracic vertebrae. The interspaces between the sixth and seventh and fifth and sixth cervical vertebrae were most frequently affected. As would be expected from this, the seventh and sixth cervical nerve roots were most often involved. The motor roots were more commonly affected than the sensory (Chart I). The osteophytic ridges found at these two levels were more prominent than those found elsewhere in nine of the twenty patients.

Laminectomy of the cervical spine was performed on all twenty patients. The laminectomy was extensive in twelve of them: four laminal arches were removed in nine patients, five in two patients, and six in one patient. In six

TABLE III

SUMMARY OF OPERATIVE FINDINGS

Case	Site of Hypertrophic Laminal Arch	Arachnoid Adhesions *	Dilatation of Cord Vessels *	Swollen Nerve Roots	Atrophic Nerve Roots	Tension of Dentate Ligaments *	Site of Herniation of Disc
1							
2	C3	+++	++		C4, left	++	
3	C5	++	++		C4, right		
4		++	++		C5 and 6, bilateral	++	
5				C7, right			C6-C7
6	C7	++	+++	C6 and 7, left		++	
7		+	++	C7, right		++	
8	C3	+++	++				
9		++	++	C6 (motor), right		++	C5-C6
10	C5	++	++			+	
11		+	+				
12							
13		++	++	C6 and 7, left; C6, right		+	
14		+++	+++	C5, right		++	
15						+	C5-C6
16		++	+++	C4 and 6, bilateral		++	
17		+	++				
18		++	++				
19		++	+++			+	
20		++	+++			+	

* + = Demonstrable; ++ = Definite; +++ = Obvious.

patients three laminal arches were removed. In two patients the laminectomy was limited to two segments (Table II). Foraminotomy was performed in fifteen patients. The number of unroofed foramina varied from one to three in each instance. The arachnoid membrane in the exposed area was excised in fourteen patients. The dentate ligaments were resected bilaterally in nineteen patients. In one instance, the osteophytic ridge was partially removed in order to relieve pressure on the axilla of the nerve root (Case 12). In two patients (Cases 6 and 7), because of the marked swelling of the nerve roots, the dural sheath was incised for the purpose of decompression (Table III).

The operative findings, besides the osteophytic ridges and constricted intervertebral foramina, are summarized in Table III. These findings have been seldom mentioned in the literature. A hypertrophic laminal arch was found in five patients, arachnoid adhesions in sixteen, and increased vascularity and dilatation of blood vessels of the cord in sixteen. Congested and swollen nerve rootlets were noted in seven patients; in three of these patients, the intradural course of the involved nerve root was markedly distorted. In one patient (Case 9) the intradural portion of the nerve root pointed 45 degrees rostrally toward its intervertebral foramen. In this instance the normal course of the nerve root was restored by an incision made along the lateral aspect of the dura. This allowed the root to displace rostrally.

Atrophic nerve roots were noted in three patients. Displacement of the spinal cord and increased tension of the dentate ligaments were demonstrable in twelve patients. A ruptured intervertebral disc was found in three instances.

The surgical results in fifteen patients were evaluated in this study. The

follow-up period varied from one year to three years and eight months. Five patients were excluded; one patient died a month after surgery from myocardial infarction, and for the other four patients the follow-up period was less than one year and therefore considered inadequate for evaluation.

All pain was completely relieved in eight patients. Recurrence of pain in the shoulder and upper arm occurred in one of these eight patients seven months after surgery; incomplete relief of pain was noted by four patients; and three others required infrequent small doses of narcotics for their pain. Improvement in motor function of the lower extremities was noted in twelve patients, including three paraplegics. Recovery was complete in three patients, partial in six patients, and minimal in three patients. Functional improvement in the hands and arms was considered satisfactory in seven patients and partial in five patients (Table II). No improvement was noted in two patients. Recovery of strength in atro-

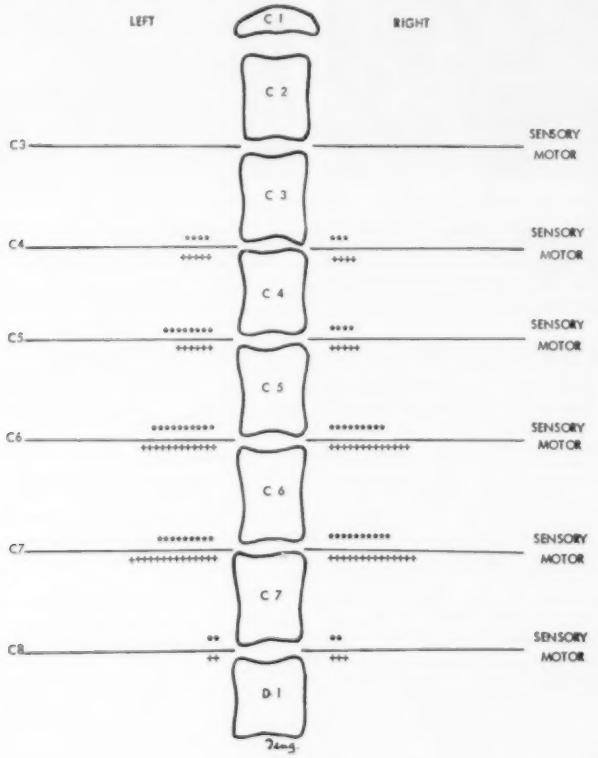

CHART I

Diagram of the compression of the nerve roots in twenty surgically treated spines. Note that the sixth and seventh cervical nerve roots are the most frequently involved, the motor more than the sensory. Each + or * indicates one instance of nerve involvement at that level, * = sensory nerve; + = motor nerve.

phied muscles of the shoulder and arm was slow and partial in five of the patients, but no recovery of the atrophied small muscles of the hand was noted in any of the patients operated on. Fasciculations gradually disappeared in five of eight patients.

Although the operation had freed all seven patients from the thoracic pain, a sensory level of hypalgesia remained demonstrable in seven. However, compared with before operation, the hypalgesia had become less conspicuous, and in

FIG. 1

FIG. 2

Fig. 1: Case 15. The myelogram shows defects at the interspaces between the third and fourth and the fourth and fifth cervical vertebrae, which at operation were demonstrated to be caused by cartilaginous spurs.

Fig. 2. Case 4. Myelogram made with the pantopaque in caudal flow, with an obstruction noted at the interspace between the third and fourth cervical vertebrae.

five patients had receded two or three segments below the original level.

Five patients had improvement in function of the urinary bladder after operation, but three of these still had hypotonicity.

ILLUSTRATIVE CASES

To illustrate the various pathological and anatomical changes in spondylosis of the cervical spine, five illustrative cases are presented in detail. Each case represents a different manifestation of the disease with respect not only to symptomatology but also to pathology.

CASE 15. A man, forty-two years old, had been in a minor automobile accident one year before admission. He had received a so-called whiplash injury and thereafter noted the development of a sharp pain radiating along the radial side of the left arm and hand. Associated with the pain there was also some weakness of this extremity.

Examination showed limitation in lateral movements of the neck. Atrophy and fasciculations were noted in the muscles of the left shoulder girdle. Marked weakness was found in flexion and extension of the left elbow, and in extension of the wrist and the three fingers on the radial side of the hand. Hypalgesia was demonstrated along the distribution of the left fifth and sixth cervical nerve roots. Slight weakness was also found in the left lower extremity. The deep-tendon reflexes of the left upper limb were depressed, and those of the left lower limb were hyperactive.

Roentgenograms of the cervical spine showed a slight reversal of the normal curvature. A myelogram showed obliteration of the sleeves of the fourth, fifth, and sixth cervical nerve roots on the left; a lateral view during myelography demonstrated an anterior defect at the interspaces between the third and fourth and fourth and fifth cervical vertebrae (Fig. 1). Electromyography indicated severe involvement of the left fifth and sixth cervical nerves.

Neck traction and external fixation for four weeks yielded no effect. On July 3, 1956, a laminectomy was performed from the third to the sixth cervical vertebrae. A high cartilaginous ridge was found at the levels of the third and fourth, fourth and fifth, and fifth and sixth cervical interspaces, extending into the markedly narrowed intervertebral foramina of the lower two spaces. A herniated disc was removed from the interspace between the fifth and sixth cervical vertebrae, the intervertebral foramina on the left between the fourth and fifth cervical vertebrae were unroofed, and the dentate ligaments were resected bilaterally from the third to the sixth cervical vertebrae.

The patient was asymptomatic at the time of writing.

This patient was the youngest in this series. The onset of symptoms was acute after an injury. The left sixth cervical nerve root was compressed by a herniated disc, and the left fifth cervical nerve root was compressed by the cartilaginous ridge at the intervertebral foramen. Removal of the herniated disc, foraminotomy at the interspaces between the fourth and fifth and fifth and sixth cervical vertebrae, and section of the dentate ligaments effected a complete relief of symptoms.

The cartilaginous ridges were not visualized on the plain roentgenograms, but were well demonstrated by myelography. These uncalcified cartilaginous ridges presumably represent an early stage in the formation of osteophytes.

CASE 4. The patient was a man, forty-four years old, who had first noted weakness in both arms and both hands twelve years before admission. Six years later his gait became unsteady. Six months before admission he could not use his hands to feed himself. He had been told that he had amyotrophic lateral sclerosis. He was known to have aortic stenosis and insufficiency.

Examination demonstrated marked weakness in both upper limbs, associated with muscular atrophy and fasciculations. The patient's gait was unsteady, and he walked with a wide base. Marked weakness was found in both lower limbs, more on the right than on the left. A suspicious level of hypalgesia was elicited at the fourth thoracic dermatome. Temperature and vibration senses were diminished in the left lower limb. Hyperreflexia was demonstrated in all four limbs, and Hoffmann's sign was present on both sides. Tenderness was found over the spinous process of the lower cervical segments. Hyperextension of the neck produced a tingling sensation along the spine.

Roentgenograms of the cervical spine showed a reversal of normal curvature, marked spondylosis, and an osteophytic ridge at the interspaces between the third and fourth, fourth and fifth, fifth and sixth, and sixth and seventh cervical vertebrae. Deformed intervertebral foramina were demonstrated between the fourth and fifth and fifth and sixth cervical vertebrae. Manometric studies of the cerebrospinal fluid [14] showed a partial block when the neck was in the neutral position and a complete block when it was in hyperextension. Myelography with pantopaque disclosed an incomplete block at the level of the seventh cervical vertebra to rostral flow and a complete block at the level of the fourth cervical vertebra to caudal flow (Fig. 2). The total protein content of the cerebrospinal fluid was 207 milligrams per 100 milliliters.

On June 26, 1956, laminectomy was performed from the fourth to the seventh cervical vertebrae. The bone ridges at the interspaces between the fourth and fifth and fifth and sixth cervical vertebrae obliterated the caudal half of the intervertebral foramina and compressed only the motor nerve roots. The osteophytic ridge at the interspace between the fifth and sixth cervical vertebrae half closed the spinal canal, pushing the spinal cord posteriorly against the laminal arch. The dentate ligaments from the fourth to the seventh cervical vertebrae were resected bilaterally, and the intervertebral foramina between the fourth and fifth and the fifth and sixth cervical vertebrae were unroofed on both sides. Arachnoid adhesions were noted in the exposed area, and the arachnoid membrane was removed.

On the seventh postoperative day the patient could button and unbutton his shirt and feed himself, although with difficulty. Three months later his gait had become more steady than before surgery. Further improvement in motor function of the arms and hands was noted a year later, but atrophy of the small muscles of both hands remained obvious. Hoffman's sign was persistent.

This case illustrates the severe type of cervical spondylosis with involvement of the spinal cord and nerve roots, primarily of the motor portion, causing symptoms and signs simulating amyotrophic lateral sclerosis. Paralysis of the upper-motor-neuron type was caused by compression of the cord by osteophytic ridges, whereas that of the lower-motor-neuron type resulted from the compression of the motor nerve roots in the intervertebral foramina. The mechanism that produces compression of only the motor roots without sensory involvement will be discussed in a later section of this article.

CASE 2. A man, sixty-seven years old, tripped over a railway track and fell on his buttocks five years before admission. Thereafter, pain developed in the back of his neck, between the shoulder blades, and in the left arm and hand. Two years later, weakness appeared in both hands associated with numbness. One year later his gait had become unsteady. Cramps frequently occurred in both legs. For six months he had difficulty passing urine.

Examination showed that hyperextension of the neck caused a tingling sensation along his spine and pain at the base of his neck. Weakness was found in all four limbs, more in the upper than in the lower. The left hand and arm were weaker than the right. Marked muscle atrophy was noted in both upper extremities in the shoulders, arms, and hands. Fasciculations were observed in the left upper arm and shoulder. Hypalgesia was elicited along the distribution of the eighth cervical and the first thoracic nerves on both sides. A second level of vague hypalgesia was demon-

FIG. 3

FIG. 4

Fig. 3: Case 2. Myelogram showing defects at the interspaces between the third and fourth, the fifth and sixth, and the sixth and seventh cervical vertebrae.

Fig. 4: Case 16. Note the ventral defects at the interspaces between the fifth and sixth and sixth and seventh vertebrae and the posterior defects caused by arachnoid adhesions.

strated just below the clavicles. The deep-tendon reflexes were all hyperactive. Other findings were ataxia of the trunk, bilateral ankle clonus, bilateral Babinski's sign, and Hoffman's sign on the left.

Roentgenograms of the cervical spine showed a markedly narrowed interspace between the third and fourth and the fifth and sixth vertebrae. An osteophytic ridge was seen at the interspaces between the third and fourth, fifth and sixth, and sixth and seventh cervical vertebrae, with deformed intervertebral foramina at these levels. Manometry demonstrated a complete block when the neck was in hyperextension. The total protein content of the cerebrospinal fluid was 70 milliliters per 100 milligrams. Cystometry showed a hypertonic bladder. Myelograms demonstrated a consistent break in the column of pantopaque at the level of the fourth cervical vertebra (Fig. 3).

On May 15, 1957 laminectomy was performed from the third cervical vertebra to the seventh. The third cervical laminal arch and pedicles were found to be markedly thickened, forming a bone ring that tightly constricted the dural sac. During the process of removing this ring of bone the blood pressure, which had been 190 systolic, 110 diastolic, consistently, dropped suddenly to 120 systolic, 70 diastolic after the third cervical laminal arch was opened. Arachnoid adhesions found in the exposed area were easily separated from the spinal cord. The intervertebral foramen on the left between the third and fourth vertebrae was almost completely obliterated, and the fourth cervical nerve roots were atrophic; the atrophic nerve roots tightly anchored the cord to the obliterated foramen. The spinal cord was displaced backward and to the right by the bone ridges on the vertebral bodies at this interspace. The intervertebral foramina on both sides at this level were unroofed, and the dentate ligaments were resected from the second to the seventh cervical vertebrae.

One month after operation the patient's hand grip was stronger than before. He could walk a straight line with quick steps. The muscle cramps had disappeared, cystometry showed improvement in bladder tonicity, and the ankle clonus and Babinski's sign had disappeared. However, thirty months later muscular atrophy of the upper arms and shoulders remained obvious.

The traction effect exerted on the cord by the atrophic nerve roots in this case is unusual. In addition to this, the tense dentate ligaments exerted a similar effect on the cord, which was displaced backward and to the right. Another unusual finding was the thickened third cervical laminal arch and pedicles. All these factors together with the ventral bone ridge caused compression of the spinal cord from four directions. The decompression, which included laminectomy, section of the dentate ligaments, and foraminotomy, effected a satisfactory, although incomplete, relief of symptoms.

CASE 16. A man, fifty-seven years old, complained of a feeling of pressure in the rectum,

associated with itching in the perineal region, that had existed for two years. Six months after the onset of symptoms weakness appeared in his right hand, arm, and leg. He could not feel hot or cold in either leg. Numbness was noted in both hands.

Examination showed tenderness on pressure over the spinous process of the lower cervical segments. Weakness, which was elicited in both arms and hands, was more pronounced on the right than on the left. Atrophy was observed in both shoulders and fasciculations were observed in the muscles of both shoulders. His gait was unsteady, and he walked with a wide base. In the right lower extremity there were muscle weakness and a loss of vibration sense. Temperature sensation was markedly impaired in both legs, more on the left than on the right. In both legs position sense was preserved and there were hyperactive reflexes and Babinski's sign.

A high osteophytic ridge was seen at the fifth to sixth and sixth to seventh cervical interspaces, both on plain roentgenograms and on the myelogram (Fig. 4). The intervertebral foramina at the interspace between the fifth and sixth vertebrae were markedly obliterated. Manometry showed a partial block when the neck was in hyperextension. The total protein content of the cerebrospinal fluid was 85 milligrams per 100 milliliters.

Surgical treatment was rejected by the patient.

One year later he was again admitted, now quadriplegic. On June 14, 1957, laminectomy was performed from the fourth to the seventh cervical vertebrae. The bone ridge at the fifth to sixth cervical interspace was seen, extending laterally into the intervertebral foramina which were so markedly obliterated that the finest probe would not pass through either one. The fourth and sixth cervical nerve roots were swollen and congested. The dentate ligaments from the fourth to the seventh cervical vertebrae were bilaterally resected, and both intervertebral foramina at the interspace between the fifth and sixth vertebrae were unroofed.

After operation the patient was mentally confused, disoriented, and hallucinated for six days. One and a half months after operation he could make a weak grip with his right hand. Temperature and vibration sensations returned in both lower limbs. Babinski's sign could be elicited only on the right side. Improvement of motor function was not observed until seven and one-half months later. Two years after operation, the patient's gait remained ataxic and unsteady, and he can only walk about the house with the aid of a cane. He uses his left hand with marked difficulty but can hold objects with the right.

This patient had advanced spondylosis with marked involvement of the cord and nerve roots resulting from delayed treatment.

Case 14. A man, forty-eight years old, had become "paralyzed from below the neck" after diving into a swimming pool twenty-six years before. After the injury he was taken to a hospital where neck traction was applied. On the next day he fell off the bed and was accidentally hanged by the neck and was then unconscious for five weeks. After he became conscious he found that he had regained strength in the left limbs, but the right limbs remained paretic. Five months before admission there developed a sharp pain in the back of his neck and in the right shoulder and arm. In addition, there was weakness in all four extremities which was more pronounced on the right than on the left side.

Examination showed marked tenderness over the spinous process of the fourth and fifth cervical vertebrae. Hyperextension of the neck caused pain in the right shoulder and arm. Weakness was elicited in both arms, but was most marked in the right hand, arm, and leg where it was associated with hypertonicity. Atrophy and fasciculations were noted in the right triceps, and atrophy was also noted in the small muscles of the right hand. Hypalgesia was found from below the fourth thoracic dermatome on both sides, being more distinct on the left than on the right side. Vibration sensation was absent in both lower limbs, and temperature sensation was impaired on the left side. Other findings included hyperreflexia and Babinski's sign on the right side and a bilateral Hoffman sign.

Roentgenograms of the cervical spine showed a reversal of the normal curvature. The fourth and fifth cervical vertebral bodies appeared to be fused to one another, and an exostosis bulged into the spinal canal at the fifth cervical vertebra. An osteophytic ridge which was clearly visualized in a cervical myelogram was present at the interspace between the fifth and sixth vertebrae (Fig. 5). Manometry showed a partial block when the neck was in hyperextension. The total protein content of the cerebrospinal fluid was 60.5 milligrams per 100 milliliters.

On July 24, 1957, laminectomy was performed from the fourth to the seventh cervical vertebrae. A large bone mass, smooth in contour and measuring about two centimeters in diameter, was found at the interspace between the fourth and fifth vertebrae. The fifth cervical nerve roots were stretched taut. An osteophytic ridge was located at the interspace between the fourth and fifth vertebrae. The right intervertebral foramen between the fourth and fifth vertebrae was markedly deformed. Foraminotomy was performed on the right side at this level, and the dentate ligaments were sectioned on both sides from the fourth cervical to the first thoracic vertebrae.

After operation, pain in the right shoulder, arm, and hand was relieved. One month later, examination showed no motor or sensory deficit in the left limbs. The residual weakness that had persisted from the time of the accident, twenty-six years before, remained obvious in the right hand, arm, and leg.

The role of trauma in the causation of spondylosis is illustrated in this patient. The pathological change, which had been found at the site of old injury, was an exostosis. The presenting symptoms and signs in this patient were not unlike those of an extramedullary neoplasm.

DISCUSSION

The incidence of spondylosis of the cervical spine is high. Horwitz studied the cervical spines of fifty unselected cadavera with an average age of fifty-six years and found degenerative changes of the spine in 76 per cent of them. However, in comparison with the high incidence of spondylosis among older persons, involvement of the spinal cord and nerve roots is infrequent. The Southern California Permanente Health Insurance Plan (largely a family health-insurance plan) covers a population of 220,000, which includes persons of all ages, races, and different social status; it may represent a cross section of the general population. Out of these 220,000 Health Plan members, sixty-three patients with spondylosis of the cervical spine with neurological symptoms were diagnosed from February 1956 to October 1959. The youngest patient was thirty-nine, and the oldest was seventy-three years of age. Fifty-two patients were male, and eleven were female. Twenty-three patients were between forty-six and fifty-five years, and twenty were between fifty-six and sixty-five. Twenty of these sixty-three patients were treated surgically; the other forty-three patients were treated by the combination of physical therapy, external fixation of the cervical spine, traction, and bedrest. All responded favorably.

FIG. 5

Case 14. Note the exostosis on the posterior aspect of the body of the fifth cervical vertebra.

The role of trauma is usually difficult to evaluate. However, its relation to the development of symptoms has often been noted. (Clarke and Robinson found that 12.5 per cent of their patients had a history of trauma.) Eight of the twenty surgically treated patients in the present study related definite traumatic injury to the cervical spine. The incidence of trauma in this group of patients is considerably higher than in those treated conservatively. Only four of the group of forty-three patients treated conservatively had a history of neck injury. In general, it seems that trauma may produce symptoms in three ways:

Trauma may cause a herniation of the intervertebral disc and the subsequent formation of spurs typical of a cervical spine with spondylosis[15]. In Case 15 trauma presumably produced herniation of the intervertebral disc and the subsequent degenerative changes with the formation of cartilaginous ridges that were visualized only on the myelogram. These cartilaginous ridges probably represent an early stage in the development of spondylosis.

Secondly, trauma may cause compression of the spinal cord and nerve roots in a previously asymptomatic spondylotic spine.

Thirdly, trauma may aggravate the symptoms in established spondylotic myelopathy.

The osteophytic ridge is formed by the apparent fusion of an upper and lower hypertrophic lip, arising from adjacent vertebrae. It projects not only into

FIG. 6

FIG. 7

Fig. 6: Cadaveric specimen. The arrows indicate the motor nerve roots and their position in the lower half of the intervertebral foramen. Note the deformity of the lower foramen and the rostral displacement of the motor nerve root in the lower interspace (black arrow).

Fig. 7: An enlarged oblique view of the intervertebral foramina between the fifth and sixth and the sixth and seventh cervical vertebrae. Note the deformity of the foramen between the fifth and sixth cervical vertebrae, more in the lower half than in the upper, and the formation of the osteophytic ridge by the apparent fusion of two hypertrophic lips.

the spinal canal, but also extends laterally into the intervertebral foramen, deforming it and causing compression of the nerve roots. The formation of the intervertebral foramen is diagrammed in Chart II. The sensory nerve roots are larger than the motor nerve roots and are located largely in the upper portion of the foramen rostral and posterior to the motor nerve roots. The motor nerve roots are ventral and caudal to the sensory nerve roots and located in the lower half of the foramen (Fig. 6). This relationship has been demonstrated consistently not only at surgery but also in five cadaveric dissections. The lateral extension of a larger inferior lip deforms the lower half of the intervertebral foramen (Chart II, *D*) and, thereby, may produce compression upon only the motor nerve roots without irritation to the sensory fraction. This was well demonstrated in Case 2. This patient presented symptoms not unlike amyotrophic lateral sclerosis. On the other hand, if the deformity involves only the upper portion of the foramen, it causes compression of the sensory nerve roots (Chart II, *B*). In the majority of cases of spondylosis, both nerve roots are involved as a result of deformation of the whole intervertebral foramen (Chart II, *C*). This often can be clearly demonstrated in an oblique view of the cervical spine (Fig. 7). In addition to the preceding anatomical explanation for the differential involvement of the motor and sensory nerve roots there is also a physiological reason for the difference since the motor nerves are more susceptible than the sensory nerves to ischemia caused by compression.

In spondylosis, the hypertrophic changes also involve the pedicles and the laminal arches. Both structures may become thickened and cause compression of the spinal cord, as was observed in Case 2. In the lumbar region where the intervertebral foramina are large and the spinal canal is wide, spondylosis rarely causes compression of the nerve roots at the intervertebral foramina, but an

osteophytic ridge and a markedly thickened laminal arch may cause a complete block of the spinal canal and compression of the cauda equina, as was observed in five cases[23].

Frykholm made the observation that narrowing of the cervical intervertebral space shortens the cervical spine in relation to the spinal cord and therefore tends to displace the nerve roots caudally in the foramina. As a result, the nerve roots may be subjected to pressure by the edge of the intervertebral foramen which is not itself narrowed by osteophytes. One instance of this situation was observed in this series in Case 9.

In the patients reported here the factors contributing to the production of symptoms and signs of involvement of the cord may be summarized as follows:

1. Posterior or posterolateral displacement of the spinal cord by osteophytic ridges;

2. "Varicosity" of the spinal cord as a result of complete or partial obstruction of the spinal canal. Either the venous or arterial circulation to the spinal cord, or both, may be impaired. Mair and Druckman emphasized the role of the

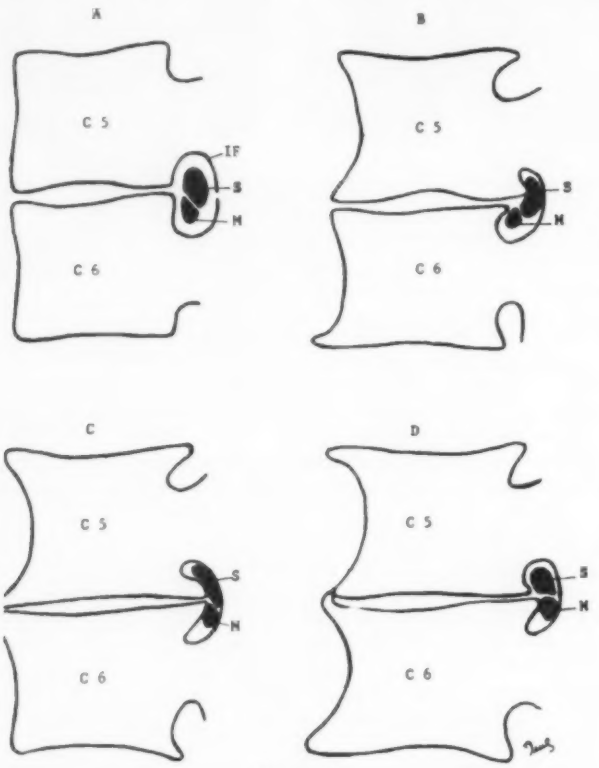

CHART II

The diagram shows the configuration of an intervertebral foramen. *A*, normal; *B*, partial deformity and compression of the sensory nerve roots; *C*, complete deformity and compression of both the sensory and motor nerve roots; *D*, partial deformity and compression of the motor nerve roots. *S* = sensory nerve roots; *M* = motor nerve roots.

anterior spinal artery in this condition. This vessel is compressed by the spondylotic changes, and the regions of the cord supplied by this vessel suffer ischemia —a conception that correlates well with the clinical findings in certain cases. Arteriosclerotic changes in patients of this age group make the affected arteries

more susceptible to trauma. Vascular compression may cause local neuronal degeneration in the anterior horn. However, retrograde neuronal degeneration may also occur, caused by compression and atrophy of the anterior spinal nerve roots at the intervertebral foramen;

3. The anchoring of the cord by the dentate ligaments helps to potentiate anterior cord compression;

4. Focal arachnoiditis may result from localized compression [11] (Table III);

5. Posterior compression of the spinal cord by a thickened laminal arch [7];

6. Posterior pressure caused by bulging or corrugation of the yellow ligaments at the level of an osteophytic ridge, particularly when the neck is hyperextended, may also be a potent factor [22]. In the present series, however, there was no abnormality of the yellow ligaments noted at operation. Measurement of the yellow ligaments showed that their thickness did not exceed two millimeters. The corrugated appearance noted in the lateral projection on the myelogram (Fig. 4) was probably caused by thickened laminal arches and arachnoid adhesions on the posterior aspect of the spinal cord. This corrugated appearance has been observed in five instances of this series.

Many articles have been written concerning spondylosis of the cervical spine [2, 3, 4, 5, 6, 18, 20, 21] and yet contributions to the surgical approach to spondylosis of the cervical spine are few. In the majority of instances, physical therapy, consisting in traction, special exercises, and external fixation, effect satisfactory relief of symptoms. In advanced cases with marked obliteration of the intervertebral foramina, conservative measures can hardly be expected to produce any effect.

When conservative treatment fails [16], surgical decompression is the last resort. The following surgical procedures were chosen in the treatment of these twenty cases: (1) laminectomy, wide and liberal, including at least one laminal arch above the uppermost and one below the lowermost bone ridge; (2) decompression of the compressed nerve roots by foraminotomy; (3) separation or excision of arachnoid adhesions, if possible; and (4) liberal section of the dentate ligaments, at least one above and one below the osteophytic ridges.

The section of the dentate ligaments as advocated by Kahn is to release the cord from its anchorage, allowing it to displace posteriorly away from the anterior ridges and to relieve the stress and strain on the intramedullary portion of the cord caused by the tension of the dentate ligaments on each side. Improvement in long-tract symptoms has often been observed after section of the dentate ligaments [24].

Frequently, a patient has become quadriplegic after a cervical laminectomy for spondylosis. It is a known fact that arteriosclerosis is a common finding in patients of this age group, and the arteriosclerotic changes of the spinal arteries may contribute to the high incidence of postoperative morbidity. At the same time, there are other factors to be considered and cautions to be taken during these surgical procedures in order to prevent damage to the spinal cord.

1. Hyperextension or excessive manipulation of the neck during intubation for anesthesia should be avoided. It is conceivable that, during the induction of anesthesia, hyperextension may further damage a spinal cord which has already been compressed and displaced by osteophytes; this additional damage may result in a permanent paralysis. Allen could invoke blanching of the cord by extending the neck at operation. Other authors [9, 19] reported that acute extension of the neck was the movement which was most likely to damage the cord. I have witnessed two instances of quadriplegia apparently related to hyperextension of the neck during induction of anesthesia.

2. Pressure exerted on the cord by any instrument used during laminectomy should be avoided. In this connection, Epstein and Davidoff emphasized that great care must be taken in removing the laminae in these patients to avoid inserting the lower jaw of the rongeurs beneath the laminal arch, as the instru-

ment may further compress and crush the spinal cord against the underlying bone ridges.

There was no postoperative death or morbidity in the series reported in this article. One patient died a month after surgery from a myocardial infarction.

The prognosis in patients with spondylosis of the cervical spine depends on the duration and degree of trauma sustained by the spinal cord and nerve roots. The longer the duration and the more advanced the symptoms and signs caused by atrophy of the spinal cord and nerve roots, the poorer is the prognosis for recovery. In early cases, a satisfactory, although incomplete, recovery of neurological functions can be expected. The relief of pain and improvement of motor function of the upper extremities depend on the adequacy of decompression of the nerve roots by foraminotomy. The relief of chest pain and the recovery of strength in the lower limbs are in large part dependent on the effectiveness of the decompression of the spinal cord produced by laminectomy, section of the dentate ligaments, and separation or excision of the arachnoid adhesions.

SUMMARY

The present communication concerns a study of twenty surgically treated cases of spondylosis of the cervical spine with compression of the cord or nerve roots, or of both. Five illustrative cases are described.

The mechanism of producing "differential" compression of either the sensory or motor nerve roots at the intervertebral foramina is discussed.

The types of surgical procedures used in these twenty cases are described, including laminectomy, foraminotomy for decompression of the nerve roots, section of the dentate ligaments, and separation or excision of the arachnoid adhesions, if present.

Special precautions during anesthesia and surgery are emphasized.

REFERENCES

1. Allen, K. L.: Neuropathies Caused by Bony Spurs in the Cervical Spine with Special Reference to Surgical Treatment. J. Neurol., Neurosurg., and Psychiat., **15**: 20–36, 1952.
2. Bailey, Pearce, and Casamajor, Louis: Osteo-Arthritis of the Spine as a Cause of Compression of the Spinal Cord and Its Roots. J. Nerv. and Ment. Dis., **38**: 588–609, 1911.
3. Bedford, P. D.; Bosanquet, F. D.; and Russell, W. R.: Degeneration of the Spinal Cord Associated with Cervical Spondylosis. Lancet **2**: 55–59, 1952.
4. Brain, Russell: Cervical Spondylosis. Ann. Int. Med., **41**: 439–446, 1954.
5. Brain, W. R.; Northfield, Douglas; and Wilkinson, Marcia: The Neurological Manifestations of Cervical Spondylosis. Brain, **75**: 187–225, 1952.
6. Clarke, Edwin, and Little, J. H.: Cervical Myelopathy. A Contribution to Its Pathogenesis. Neurology, **5**: 861–867, 1955.
7. Clarke, E., and Robinson, P. K.: Cervical Myelopathy. A Complication of Cervical Spondylosis. Brain, **79**: 483–510, 1956.
8. Epstein, J. A., and Davidoff, L. M.: Chronic Hypertrophic Spondylosis of the Cervical Spine with Compression of the Spinal Cord and Nerve Roots. Surg., Gynec., and Obstet., **93**: 27–38, 1951.
9. Fender, F. A.: A New Hazard in Cervical Laminectomy. J. Am. Med. Assn., **149**: 227–228, 1952.
10. Frykholm, Ragnar: Cervical Nerve Root Compression Resulting from Disc Degeneration and Root-Sleeve Fibrosis. A Clinical Investigation. Acta Chir. Scandinavica, Supplementum 160, 1951.
11. Girard, P. F.; Garde, A.; and Devic, M.: Contribution a l'étude anatomique des manifestations medullaires observées au cours des discarthroses. Rev. Neurol., **90**: 48–52, 1954.
12. Horwitz, M. T.: Degenerative Lesions in the Cervical Portion of the Spine. Arch. Int. Med., **65**: 1178–1191, 1940.
13. Kahn, E. A.: The Role of the Dentate Ligaments on Spinal Cord Compression and the Syndrome of Lateral Sclerosis. J. Neurosurg., **4**: 191–199, 1947.
14. Kaplan, Lawrence, and Kennedy, Foster: Effect of Head Posture on Manometrics of the Cerebrospinal Fluid in Cervical Lesions: A New Diagnostic Test. Brain, **73**: 337–345, 1950.
15. Keyes, D. C., and Compere, E. L.: The Normal and Pathological Physiology of the Nucleus Pulposus of the Intervertebral Disc. An Anatomical, Clinical and Experimental Study. J. Bone and Joint Surg., **14**: 897–938, Oct. 1932.
16. Logue, V.: Cervical Spondylosis. *In* Modern Trends in Diseases of the Vertebral Column, p. 174. Edited by R. Nassim and H. J. Burrows. London, Butterworth and Co., 1959.
17. Mair, W. G. P., and Druckman, Ralph: The Pathology of Spinal Cord Lesions and Their Relation to the Clinical Features in Protrusion of Cervical Intervertebral Discs. Brain, **76**: 70–91, 1953.

18. NUGENT, G. R.: Clinicopathologic Correlations in Cervical Spondylosis. Neurology, **9**: 273–281, 1959.
19. SCHNEIDER, R. C.; CHERRY, GLENN; and PANTEK, HENRY: The Syndrome of Acute Central Cervical Spinal Cord Injury. With Special Reference to the Mechanisms Involved in Hyperextension Injuries of Cervical Spine. J. Neurosurg., **11**: 546–577, 1954.
20. SPILLANE, J. D., and LLOYD, G. H. T.: The Diagnosis of Lesions of the Spinal Cord in Association with "Osteoarthritic" Disease of the Cervical Spine. Brain, **75**: 177–186, 1952.
21. STERN, W. E., and RAND, R. W.: Spinal Cord Dysfunction from Cervical Intervertebral Disk Disease. Neurology, **4**: 883–893, 1954.
22. TAYLOR, A. R.: Mechanism and Treatment of Spinal-Cord Disorders Associated with Cervical Spondylosis. Lancet, **1**: 717–720, 1953.
23. TENG, PAUL: Unpublished data.
24. TENG, PAUL, and SHAPIRO, M. J.: Arterial Anomalies of the Spinal Cord. Myelographic Diagnosis and Treatment by Section of the Dentate Ligaments. A.M.A. Arch. Neurol. and Psychiat., **80**: 577–586, 1958.

Unrecognized Trauma in Infants and Children

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In 1956, John Caffey presented the Mackenzie-Davidson Memorial Lecture in London and chose as his topic, "Some Traumatic Lesions in Growing Bones Other Than Fractures and Dislocations". He stated that he believed this to be the least well known and the most abused subject in the entire field of pediatrics and roentgenology.

This problem is being recognized with increasing frequency and we are presenting a group of representative cases seen in this area in recent years.

The article written by West in 1888, describing acute periosteal swellings in several young infants, thought to be rachitic in nature, on review, probably represent lesions due to unrecognized trauma. In 1935, Snedecor, Knapp, and Wilson recognized a traumatic origin of cortical thickening and metaphyseal fragmentation in describing roentgenographic studies of infants delivered by breech extraction. In a case of breech extraction to be described in this article, the identical changes occurring in unrecognized trauma are seen, but in this case the mechanism of injury is understood.

In 1946, Caffey described a total of twenty-three long-bone fractures in six infants, associated with chronic subdural hematoma. He concluded that the fractures were of traumatic origin but with obscure causal mechanism and that routine roentgenographic examination of long bones should be performed in every case of chronic subdural hematoma.

In 1950, Smith described a ten-week-old infant in whom multiple rib fractures were found, as well as fractures of the long bones. On the basis of these findings, a subdural tap was performed, confirming the presence of a subdural hematoma.

A similar case was described by Lis and Frauenberger in 1950, in which the diagnosis of subdural hematoma was suspected on the basis of the findings of multiple rib fractures.

In 1953, Astley described a group of six children with similar lesions in whom multiple metaphyseal fractures were seen. He felt that this represented a specific clinical entity and called it *metaphyseal fragility of bone*. This was described as being due to an underlying structural abnormality of the non-mineral constituents

FIG. 1-A

FIG. 1-B

Fig. 1-A: Case 1. Fracture-dislocation of the distal femoral epiphysis on the right. Multiple metaphyseal infractions involving the distal femoral metaphysis on the left and the proximal tibial metaphysis, bilaterally.

Fig. 1-B: Lateral roentgenogram showing posterior dislocation of the distal femoral epiphysis on the right and metaphyseal irregularity and fragmentation of the proximal and distal tibial metaphyses.

FIG. 1-C

Multiple evidence of trauma, represented by old fracture, partially healed, of the upper portion of the right ulna. Subperiosteal new-bone formation and mid-humeral fracture on the left; fracture of eighth right rib, posterior axillary line, which is healing.

of growing skeleton. A review of these cases, however, reveals that all of the lesions described in these children could well have been accounted for on the basis of trauma.

In 1953, Silverman described three similar cases with detailed laboratory

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Productive callus and metaphyseal irregularity, lower portion of the right tibia; and metaphyseal infractions, lower portion of the left tibia.

Fig. 2-B: Fractures of the right second and seventh ribs and the left sixth, seventh, and eighth ribs, with productive callus.

and roentgenographic investigations and concluded that these lesions were due to trauma in children with normal bones.

In 1955, Wooley and Evans reviewed the subject. They studied the family history of twelve children who were seen with lesions resembling those due to traumatic origin but in whom a history of trauma could not be obtained. On the basis of this article, it became apparent that there is no valid reason to separate the lesions seen in these children from those of traumatic origin on the presence or absence of history alone. There was also no evidence to support the fact that these children had any unusual metaphyseal fragility.

In reviewing twelve cases seen in this area recently, we have become convinced that with roentgenographic recognition of this lesion, the presence or absence of a history of trauma is unimportant. Actually, it appears as though the children with the most severe trauma were those in whom a history was least obtainable.

CASE 1. A two-month-old, white, female infant was admitted to Variety Children's Hospital on September 27, 1959, with swelling of the right thigh for forty-eight hours prior to admission. A local pediatrician had administered penicillin, twenty-four hours prior to admission, for an infection of the respiratory tract. On physical examination, the right thigh was swollen and tender, without redness or local heat. No external evidence of trauma was observed and all history of trauma was denied by the parents. The laboratory data was within normal limits. The initial roentgenographic examination on September 29, 1959, revealed a fracture-dislocation of the distal right femoral epiphysis with posterior displacement of the epiphysis. Metaphyseal irregularities of the distal femur and proximal and distal metaphysis of the right tibia were observed. A diagnosis of unrecognized trauma was made, and, on this basis, survey films were obtained. These revealed an old healed fracture of the upper part of the right ulna and cortical elevation and subcortical new-bone formation of the left humeral mid-shaft. A fracture of the posterior part of the eighth right rib was observed, as well as multiple metaphyseal infractions of the proximal and distal portions of the tibial metaphysis on the left. Following hospitalization, the lesions all began to show roentgenographic evidence of healing. Because of the complete denial of trauma on the part of the parent, this case was referred to the Juvenile Court. The Juvenile Court placed the home under surveillance, with periodic visits by a juvenile officer, and required periodic examinations of the child at Variety Children's Hospital.

CASE 2. A three-month-old, white, male child was admitted to Variety Children's Hospital on August 17, 1959, with a hard nodule of the right anterior chest wall. The child was in a foster home, as he had been abandoned at birth by the parents. The child was described as having been extremely irritable since two weeks of age. At one month of age, the child had been seen for swelling and tenderness of the right lower extremity, at which time roentgenographic investigation re-

FIG. 3-A

FIG. 3-B

Fig. 3-A: Case 3. Fractures of the distal portions of the tibia and fibula on the right, with subperiosteal new-bone formation, which are healing. Fragmentation of the left distal femoral metaphysis with subperiosteal new-bone formation.

Fig. 3-B: Subperiosteal new-bone formation of the distal portion of the left ulna.

FIG. 4-A

Case 4. Extensive and productive subperiosteal calcification of the distal portion of the right humerus. Subperiosteal calcification of the anterior surface of the right radius and ulna.

FIG. 4-B

FIG. 4-C

Fig. 4-B: Occult fracture of the distal portion of the right tibia, with subperiosteal calcification of the lateral border of the right tibial shaft. Occult metaphyseal fractures of the proximal portion of the right tibia, the proximal portion of the left tibia, and the distal portion of the left femur.
Fig. 4-C: Subperiosteal calcification of the shaft of the left ulna and the lateral surface of the shaft of the left radius.

vealed evidence of subperiosteal new-bone formation and metaphyseal irregularity of the distal tibial metaphysis on the right. A metaphyseal irregularity of the opposite distal portion of the tibia was also noted and the diagnosis, roentgenographically, at that time was traumatic lesion of bone. Abuse or poor handling was denied. On August 17, 1959, an excretory urogram was negative. However, roentgenograms made at this time revealed evidence of multiple rib fractures involving the second and seventh ribs on the right and the sixth, seventh, and eighth ribs on the left. A skull examination revealed a left parietal fracture. The child was removed from the foster home; the follow-up was uneventful.

CASE 3. This eighteen-month-old white child was first seen at Variety Children's Hospital on September 29, 1959, because of swelling of the right leg and tenderness of the right thigh of two days' duration. Three months prior to admission, a furuncle of the lower portion of the right leg had been treated with topical antibiotic ointment, with rapid clearing. Six weeks prior to admission, swelling of the lower portion of the right leg was noted which, apparently, subsided spontaneously. The past history revealed no significant disease. The parents were divorced and the mother worked, employing a baby-sitter during the daytime. Traumatic incidents were denied. The father had left home approximately three months before the child's admission. The physical examination revealed swelling of the right leg and some tenderness. There was swelling of the left thigh with minimum tenderness. Roentgenographic examination of the lower extremities revealed a productive subperiosteal callus and new-bone formation occurring in the distal portion of the right tibia. A fracture line through the distal portion of the tibia was seen, with new-bone formation of the distal portion of the right fibula and a fracture line paralleling the tibial fracture. Metaphyseal irregularity and fragmentation of the upper portion of the right tibia and metaphyseal irregularity and fragmentation of the distal portion of the left femur with early subperiosteal new-bone formation were observed. The diagnosis of unrecognized trauma was made, and survey films revealed evidence of subperiosteal new-bone formation of the distal part of the left ulna. Roentgenograms made at six weeks showed normal healing.

CASE 4. This one-year-old Negro male infant was brought to Jackson Memorial Hospital on September 30, 1959, because of unwillingness to use the right arm for two weeks. Two days prior to admission the mother noted swelling of the forehead and face with ecchymosis about the eyes. The mother denied history of definite trauma but thought that the child had probably fallen two days prior to admission. The past history was unremarkable. The physical examination revealed a hard mass about the distal portion of the right humerus with minimal tenderness, slight soft-tissue

FIG. 5-A FIG. 5-B

Fig. 5-A: Case 5. Breech extraction, forty-eight hours after delivery. Metaphyseal fragmentations in which direct mechanism of trauma is understood.

Fig. 5-B: Same knee at two weeks reveals both metaphyseal fractures and subperiosteal new-bone formation.

swelling, but no redness. Soft-tissue swelling and ecchymosis about the forehead and periorbital tissues were evident. Laboratory studies were within normal limits. The roentgenographic examination of September 30, 1959, revealed productive subperiosteal new-bone formation about the distal portion of the right humerus. Subperiosteal calcification was also noted along the distal portions of the right radius and ulna. The diagnosis of unrecognized trauma was made, and a bone survey on October 2, 1959, revealed a healing fine-line fracture of the distal part of the right tibia, with subperiosteal calcification. Metaphyseal fragmentation of the proximal part of the right tibia, the proximal part of left tibia, and the distal part of the left femur was observed. There was also subperiosteal calcification of the left radius and ulna. When confronted with the roentgenographic evidence of the numerous sites of trauma to the long bones, the mother revealed that the daytime baby-sitter, who was employed while the mother worked, was a habitual drinker and repeatedly told neighbors that the child was irritable and cried incessantly. The course in the hospital was benign and the bones showed normal healing at time of discharge, two weeks later. Four weeks after discharge, the child was readmitted with severe soft-tissue injury to the head and multiple skull fractures as shown by roentgenogram. The mother, once again, denied personal knowledge of trauma but related that the same baby-sitter was still employed.

CASE 5. This newborn baby presented as a single-footling breech. Extraction had been difficult and the obstetrician reported that considerable force was repeatedly applied to the right lower extremity, from the ankle, accompanied by a twisting motion. The mechanism of trauma was understood and necessary to effect a breech delivery, and roentgenograms, made forty-eight hours afterward, revealed occult metaphyseal fractures of the distal portion of the right femur and proximal portion of the tibia. The roentgenograms made two weeks later revealed the subperiosteal new-bone formation and metaphyseal changes which represent healing metaphyseal fractures.

DISCUSSION

Although a history of trauma was unobtainable in each of these patients on admission, there is strong indirect evidence in each to indicate that trauma was actually the predisposing factor. In some cases, the roentgenographic evidence of trauma is very obvious, in which a fracture in one or more long bones or flat bones can actually be demonstrated. In others, the subtle metaphyseal fractures are not so obvious. However, the explanation of metaphyseal fragmentation by Caffey seems to explain this lesion. That the penetrating fibers of Sharpey, which are the principal attachments of periosteum to underlying bone, are scarce in young bones and that periosteal blood vessels are abundant and circulation is active explain the ease with which the periosteum is stripped from young bone and the sizable periosteal hemorrhage beneath it. The subperiosteal hemorrhage

will calcify and become visible by roentgenogram in seven to fourteen days, the earlier time occurring in infants. The firmest attachment of the periosteum in young bones occurs at the insertion of the perichondrium into the metaphyseal ends of the bone. With twisting or shaking injuries, the deep anchoring or penetrating fibers of the perichondrium will lift up the cortex of the distal metaphysis. These small metaphyseal fractures, if seen very early, before the occurrence of subperiosteal calcification, can, in truth, be perplexing. Although a shaking or twisting type of injury will produce the metaphyseal infractions, more severe aggression, such as striking or throwing a child, may well result in frank long or flat-bone fractures. Therefore, in a child who is seen with a picture of metaphyseal infractions, complete bone surveys should be done; often other sites of fracture or subperiosteal calcification will be revealed.

An attempt should be made to determine the age of the various fractures so that it can be determined if the case represents a single injury or periodic accumulation of injuries occurring at varying times. The particular association of fracture and dislocation, which was well demonstrated in Case 5, should afford the examining physician an opportunity to make an absolute diagnosis, since the occurrence of fractures with dislocation can be explained only on a traumatic basis. The early recognition of the traumatic origin of these lesions is of great importance in preventing more serious complications in these children. Fisher, in 1958, reported four cases in which the diagnosis of traumatic lesions in children was made primarily on a roentgenographic basis. Two of these children subsequently died; in both cases a murder conviction was obtained against one or both parents.

SUMMARY

A group of cases of traumatically induced bone lesions is presented. In none of these patients was there any history of trauma obtainable at the time of admission. Subsequent studies were felt to confirm the fact that these cases were all due to trauma. This subject was reviewed and the following points are felt to be particularly significant.

The diagnosis of traumatic injury to young bones should be made with a relative degree of certainty on the initial roentgenographic examination and confirmed by survey films of the long bones. The recognition of trauma induced by adults or older siblings will save considerable time and effort in an attempt to arrive at a diagnosis. The early recognition of the condition may be lifesaving, for removal of the child, if at all possible, from the environment in which these injuries occur should result in complete cure. Close cooperation with enlightened juvenile authorities can be invaluable.

REFERENCES

1. Astley, Roy: Multiple Metaphyseal Fractures in Small Children (Metaphyseal Fragility of Bone). British J. Radiol. **26**: 577–583, 1953.
2. Caffey, John: Multiple Fractures in the Long Bones of Infants Suffering from Chronic Subdural Hematoma. Am. J. Roentgenol., **56**: 163–173, 1946.
3. Caffey, John: Some Traumatic Lesions in Growing Bones other than Fractures and Dislocations: Clinical and Radiological Features. British J. Radiol., **30**: 225–238, 1957.
4. Fisher, S. H.: Skeletal Manifestations of Parent-Induced Trauma in Infants and Children. Southern Med. J., **51**: 956–960, 1958.
5. Lis, E. F., and Frauenberger, G. S.: Multiple Fractures Associated with Subdural Hematoma in Infancy. Pediatrics, **6**: 890–892, 1950.
6. Silverman, F. N.: Roentgen Manifestations of Unrecognized Skeletal Trauma in Infants. Am. J. Roentgenol., **69**: 413–427, 1953.
7. Smith, M. J.: Subdural Hematoma with Multiple Fractures. A Case Report. Am. J. Roentgenol., **63**: 342–344, 1950.
8. Snedecor, S. T.; Knapp, R. E.; and Wilson, H. B.: Traumatic Ossifying Periostitis of the Newborn. Surg., Gynec., and Obstet., **61**: 385–387, 1935.
9. West, S.: Acute Periosteal Swelling in several Young Infants of the same Family, Probably Rickety in Nature. British Med. J., **1**: 856–857, 1888.
10. Wooley, P. V., and Evans, W. A.: Significance of Skeletal Lesions in Infants Resembling Those of Traumatic Origin. J. Am. Med. Assn., **158**: 539–543, 1955.

Pyogenic Osteomyelitis and Arthritis of the Spine Treated with Combinations of Antibiotics and Gamma Globulin

A Preliminary Report

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This is a report of eight cases with proved or presumptive diagnoses of nontuberculous, pyogenic osteomyelitis and arthritis of the spine which responded well to therapy with a combination of antibiotics and human gamma globulin. I should like to make it clear at the onset that I do not intend to suggest that these medical measures should replace the cornerstones of therapy of bone and joint infection: rest, immobilization, and the establishment of adequate drainage. However, the experience to be reported here suggests that when these measures, particularly surgical drainage, are not possible for one reason or another, antibiotics combined with gamma globulin may effect a satisfactory clinical response in certain cases of osteomyelitis.

The rationale for the combining of antibiotics with gamma globulin is provided by the work of Fisher, who showed that subcurative doses of antibiotics combined with subcurative doses of gamma globulin were able to cure mice of infections due to various bacteria. This work has subsequently been confirmed both in mice and in patients [12, 13, 15].

Case 1. A white man, forty-nine years old, was hospitalized in February 1954 because of pain in his back which came on following an injury. Roentgenograms of the spine made on December 10, 1953 (Figs. 1-A and 1-B), revealed a destructive process involving the contiguous surfaces of the twelfth thoracic and first lumbar vertebrae. A diagnosis of tuberculosis of the spine was made, and therapy with streptomycin and isoniazid was started, combined with immobilization and rest in recumbency. Seven weeks later roentgenograms showed progression of the process, and spine fusion was performed in April 1954. Six months later, tenderness and fullness in the left lumbar area were noted. The pus which was aspirated from this area revealed a pure culture of *Staphylococcus aureus*.* Incision and drainage were carried out in this area. Persistent, profuse purulent drainage resulted, which gradually decreased in amount until it ceased completely six months later in June 1955. In August 1955 the patient again became febrile, and a draining sinus developed in the region of the original operative incision. Staphylococci were again cultured with ease from the sinus, and extensive studies for tuberculosis, brucellosis, and fungi were negative. *In vitro* studies showed the staphylococci to be sensitive to penicillin and streptomycin, and a four-week course of therapy was given as follows: penicillin, 20,000,000 units intravenously daily in 500 milliliters of 5 per cent dextrose in water, and 400,000 units intramuscularly at six-hour intervals; and streptomycin, 0.5 gram intramuscularly twice a day. In addition, the sinus was irrigated daily with neomycin in a concentration of 2 milligrams per milliliter of saline solution. With this therapy the patient became afebrile, but the drainage from the sinus continued and persisted during the next year from November 1955 to November 1956, despite the oral administration of, first, novobiocin and then chloramphenicol in dosages of 2 grams a day given for two weeks. During this time, an almost identical sinus opened in the right lumbar region and began to drain. The daily drainage from these two sinuses often exceeded a pint of pus at the time when the patient was re-admitted to the hospital in September 1956. During this hospital admission roentgenograms of the thoracic spine with lipiodol injected into the sinus showed many branches of the sinus tracts that led to the bodies of the thoracic and lumbar vertebrae (Figs. 1-C and 1-D).

The work of Fisher became known to me at this time, and it was decided to administer a combination of chloramphenicol, gamma globulin, and streptomycin. The following dosage was

*All staphylococci mentioned in this paper were coagulase positive.

administered for twelve days: chloramphenicol, 0.5 gram intravenously in 200 milliliters of 5 per cent dextrose in water twice a day; chloramphenicol, 0.5 gram by mouth every eight hours; gamma globulin, 10 milliliters intramuscularly each day; and streptomycin, 0.5 gram intramuscularly four times a day. Staphylococci isolated from the wound prior to this course of therapy (September 1956) were resistant to 100 micrograms per milliliter of penicillin and 100 micrograms per milliliter of streptomycin, but were sensitive to 12 micrograms per milliliter of chloramphenicol as deter-

FIG. 1-A

FIG. 1-B

Figs. 1-A through 1-G: Case 1. Chronic osteomyelitis of the twelfth thoracic and first lumbar vertebrae due to *Staphylococcus aureus*.

Figs. 1-A and 1-B: Roentgenograms made on December 10, 1953, showing the lesion that was diagnosed as being tuberculous.

FIG. 1-C

FIG. 1-D

Roentgenograms made after the injection of lipiodol into the sinus, showing the sinus tract leading to the bodies of the lower dorsal and upper lumbar vertebrae. (Fig. 1-D is reprinted by permission from Antibiotics and Chemotherapy, Volume 7, Page 325, 1957.)

mined by the tube dilution test. The drainage decreased remarkably after the institution of this therapy and at the end of ten days it had ceased entirely. The patient was discharged from the hospital in October 1956 but he continued to receive 2 grams of chloramphenicol a day by mouth and 10 milliliters of gamma globulin intramuscularly three times a week. This therapy was continued until February 1957, during which time he was afebrile and feeling well. Gamma globulin was then decreased to intramuscular injections of 10 milliliters twice a week. Two weeks after this a slight fever developed along with some drainage and tenderness in the region of the sinuses, which subsequently subsided when the gamma-globulin injections again were increased to three times a week. The patient was then continued on chloramphenicol, 2 grams a day, and gamma globulin, 10 cubic centimeters intramuscularly three times a week until July 1, 1957, when the dosage of gamma globulin was reduced to 10 cubic centimeters intramuscularly two times a week. Within two weeks the back again became red and tender, and the patient became febrile. This inflammation subsided once again when the gamma-globulin therapy was increased at this time to three times a week. In October 1957 the dosage of gamma globulin was again decreased to two times a week, and again swelling, redness, and fever returned. As before, this subsided when the

FIG. 1-E

FIG. 1-F

Figs. 1-E and 1-F: Roentgenograms made on June 5, 1959, showing healing of the lesions.

gamma-globulin injections were increased to three times a week. During the later part of November 1957 the patient began to complain of blurring of vision. An ophthalmologist discovered changes in the retina and in the visual fields compatible with optic neuritis. All medication was stopped, and the patient remained without fever or evidence of local inflammation until January 20, 1958, when he again became febrile, and a draining sinus developed. Cultures of this sinus showed staphylococci that were sensitive to the tetracyclines but resistant to chloramphenicol, erythromycin, and penicillin. It was decided to institute maximum therapy with tetracycline, gamma globulin, and autogenous vaccine since the patient was having a spiking temperature which rose to 103 degrees Fahrenheit each day. He was given 10 milliliters of gamma globulin three times a week, 0.5 gram of tetracycline four times a day by mouth, and increasing dosages of autogenous vaccine three times a week. The dosage of vaccine was increased until he tolerated 0.5 milliliter intradermally three times a week without reaction. There was a favorable response to this program, and within ten days the patient became afebrile, and drainage stopped. This program was continued for three months, and then the dosage of gamma globulin was reduced to 10 milliliters twice a week, and the vaccine was given only once a week. At the end of six months the administration of gamma globulin was reduced to once a week, and in January 1959 the gamma globulin and vaccine were discontinued. The patient continued to take 2 grams per day of tetracycline by mouth and has tolerated this dosage of tetracycline for eighteen months without untoward reaction. The patient's visual fields and vision returned to normal three months after the cessation of chloramphenicol. Periodic studies of his hemoglobin, white blood cells, sedimentation rate, urine, non-protein nitrogen, and serum protein from 1957 to the time of writing revealed no significant abnormalities. Numerous studies of the electrophoretic pattern of his serum have always been within normal limits. The sedimentation rate rose during the exacerbations of fever and drainage, but during 1958 and 1959 it was under 10 millilimeters per hour. Roentgenograms of the spine (June 5, 1959) showed progressive healing of the lesions. (Figs. 1-E and 1-F).

This case, which was reported previously [15], suggested that gamma globulin

might be a useful adjunct in the treatment of osteomyelitis that was not amenable to surgery. This patient's course since the first report has continued to substantiate the effectiveness of gamma globulin. On three separate occasions exacerbations occurred when the gamma-globulin dosage was reduced, and each time they were controlled when the frequency of the injections of gamma globulin was increased. Other important points emphasized by this patient's case are:

1. The period of chronicity of wound infections and osteomyelitis which develop after surgery on the spine, despite antibiotic therapy—six years in this case;

2. The control of a resistant infection by long-term suppressive therapy, which in this instance may have to be continued indefinitely if it is tolerated;

3. The value of sensitivity studies, which in this case showed that the last strain isolated from the wound was resistant to chloramphenicol and erythromycin and sensitive to tetracycline, thus indicating the proper choice of a new antibiotic when the development of optic neuritis forced discontinuance of chloramphenicol.

The role of the autogenous vaccine in this patient's course could not be evaluated. There is no indication at this time whether it was helpful. The points of interest in this regard were that the patient initially exhibited a greater hypersensitivity to a vaccine prepared from his own killed organisms than to one prepared from other organisms and that desensitization to the autogenous vaccine was easily accomplished.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Case 2. Lateral roentgenogram of the lumbosacral spine, made on May 13, 1953, before operation.

Fig. 2-B: Lateral roentgenogram made on February 14, 1958, four years and five months after the onset of infection, showing narrowing and probable partial fusion of the interspace, with the vertebral bodies otherwise almost intact.

CASE 2. A man, seventy-one years old, had been operated on in June 1953 for a herniated intervertebral disc (Fig. 2-A). One week after this operation he became febrile. The cause of the fever was not manifest until ten days had elapsed, when thrombophlebitis of the left leg and stiffness of the neck were noted. Lumbar puncture revealed yellow spinal fluid which clotted in the collecting tube. The concentration of sugar in this fluid was 12 milligrams per 100 milliliters. No growth was obtained on culture. A diagnosis of septic thrombophlebitis and meningitis was made, and therapy with chlortetracycline and erythromycin was begun. The spinal-fluid sugar concentration became normal, but the fever continued, and seven weeks later a blood culture grew *Staphylococcus aureus*. This organism was sensitive to a concentration of less than 0.38 microgram per milliliter of erythromycin, and therapy for one month with this antibiotic resulted in a normal temperature.

The patient was then essentially well for three years (until July 1956), at which time he be-

TABLE I

DATA ON THE ADMINISTRATION OF DRUGS IN CASE 2

Date of Administration	Drug Administered	Bacteriostatic Activity One Hour after Injection	Bactericidal Activity One Hour after Injection
September 12, 1957	Erythromycin, 1 gram, intravenously	1:16	Growth in 1:1 dilution of patient's serum
September 13, 1957	Gamma globulin, 20 cubic centimeters, intramuscularly, and erythromycin, 1 gram, intravenously	1:32	Growth in 1:1 dilution of patient's serum
September 14, 1957	Vancomycin, 1 gram, intravenously	1:4	Growth in 1:1 dilution of patient's serum
September 15, 1957	Gamma globulin, 20 cubic centimeters, intramuscularly, and vancomycin, 1 gram, intravenously	1:8	Growth in 1:1 dilution of patient's serum

came febrile and complained of severe back pain. His temperature ranged each day from 99 to 103 degrees Fahrenheit. A roentgenogram of his spine at this time revealed extensive destruction of the fifth lumbar vertebra which was thought to be the result of postoperative osteomyelitis. He was admitted to St. Joseph's Hospital, Milwaukee, on September 11, 1956, for treatment and placed on strict bedrest. The following antibiotics were administered: 3.75 grams of novobiocin given orally over a five-day period, when the emergence of the characteristic rash forced discontinuance of this medication; 20 grams of erythromycin given intravenously over a ten-day period; 2 grams of neomycin given intravenously for two days; 10 grams of neomycin given intramuscularly for five days; and 20 grams of streptomycin given intramuscularly for ten days. These agents were used singly and in various combinations, but the patient continued to have a spiking temperature each day that ranged as high as 103 to 104 degrees Fahrenheit.

Since there was no apparent effect from the antibiotics, and the patient's general condition seemed to be deteriorating, a trial of gamma globulin and chloramphenicol in combination was deemed justified. The following were given for fourteen days: chloramphenicol, 0.5 gram given orally four times a day; streptomycin, 1 gram given intramuscularly once a day; and gamma globulin, 10 milliliters given intramuscularly once a day. After four days of this therapy the temperature became normal. Concomitant with this there was the feeling of complete well-being and a decrease in back pain. Roentgenograms of the lesion made three months after the completion of therapy showed definite signs of healing in the area of the infected vertebra. The patient was discharged on December 8, 1956.

The patient received no specific medication after discharge from the hospital and remained essentially well until July 1957, when he again noted the onset of chills, increased low-back pain, and elevation of temperature. Roentgenograms now showed changes suggestive of the reactivation of the osteomyelitis in the lumbar region, so he was readmitted to the hospital on July 20, 1957, put on strict bedrest, and given the medications that had given the favorable clinical response during his last admission: chloramphenicol, 1 gram a day by mouth, and gamma globulin, 20 milliliters a day intramuscularly initially and 10 cubic centimeters every day. When he continued to have a spiking temperature after six days of this therapy, 0.75 gram of erythromycin by mouth was added to the other antibiotics which he was receiving, but despite this and the daily gamma-globulin injections he continued to have a fever. When he was seen in consultation on August 5, 1957, he had been receiving 10 milliliters of gamma globulin daily, and 1 gram of chloramphenicol and 0.75 gram of erythromycin daily for twenty-two days. The dosage of chloramphenicol was then increased to 2 grams a day, combined with 10 cubic centimeters of gamma globulin given intramuscularly three times a week. After four weeks on this program the patient was still febrile, so all chemotherapy was stopped. Forty-eight hours later the patient had a high spiking temperature, and two blood cultures revealed coagulase-positive staphylococci. These were the first positive blood cultures for this organism since his surgery and meningitis four years before. The organisms isolated from his blood were inhibited by 25 micrograms per milliliter of chloramphenicol, 25 micrograms per milliliter of penicillin, 12 micrograms per milliliter of erythromycin, 25 micrograms per milliliter of tetracycline, 3 micrograms per milliliter of vancomycin, and 0.38 microgram per milliliter of novobiocin.

Studies to determine the best possible combinations of agents were then undertaken. Erythromycin and vancomycin were administered to the patient, and blood samples were drawn to determine which agents produced the best activity of the serum against a 1:100 dilution of an eighteen-hour growth of the staphylococcus isolated from the patient's blood. Control blood samples, drawn

before the administration of the various agents, had bacteriostatic activity in a dilution of 1:4 but no bactericidal activity. The data are given in Table I.

The patient continued to have a high spiking temperature, and on September 15, 1957, after the studies with the antibiotics and gamma globulin were completed, but before the results were known, he was started on 2 grams a day, administered intravenously, of vancomycin in 500 cubic centimeters of 5 per cent dextrose in water. On September 16, 1957, an area of exquisite tenderness in the left lower quadrant of the abdomen was found which suggested the start of a localized abscess. When the results of the *in vitro* and *in vivo* studies were available, erythromycin was added to the vancomycin, and the patient received 2 grams of erythromycin and 2 grams of vancomycin intravenously each day. It is of some interest that despite the greater *in vitro* sensitivity of the organism to vancomycin, erythromycin appeared to be the more active in the patient's serum. The area of tenderness in the left lower quadrant continued, but with the start of the intravenously administered vancomycin and erythromycin combined with daily intramuscular injections of 10 cubic centimeters of gamma globulin, the temperature finally began to come down. Therapy with the three drugs was continued from September 16 to October 14, 1957, when it was discontinued. On October 17, 1957, the area of inflammation in the lower left quadrant pointed, and a large abscess was incised and drained. Culture of this pus revealed *Aerobacter aerogenes* but not staphylococci. After drainage of the abscess the vancomycin and erythromycin were stopped. The patient was then started on 1 gram of ristocetin given intravenously daily because at this time it was thought that ristocetin might be more bactericidal than other antibiotics. Twenty-four hours after the administration of ristocetin was started, the patient began to complain of difficulty in hearing, and within thirty-six hours was completely deaf. He has never regained his hearing. However, following the drainage of the abscess and the starting of the ristocetin, the patient remained afebrile; the ristocetin was given for ten days. When the abscess in the left lower quadrant was drained, it was found to extend over to the right side, and a stab wound was made in the right flank, and a drain was inserted; a draining sinus developed here. On October 25, 1957, lipiodol was placed in this sinus and found by roentgenographic study to extend into the region of the fourth and fifth lumbar vertebrae, the site of the initial infection. The patient remained afebrile and well, and by the time of discharge from the hospital on November 8, 1957, he had received no specific chemotherapy for two weeks. There had been no further drainage from any site at the time of writing, and roentgenograms made in February 1958 show what appears to be bone fusion between the bodies of the fourth and fifth lumbar vertebrae (Fig. 2-B).

This case exemplifies the chronicity of disc-space infections since the bacteremia which occurred four years after the initial operation was caused by the same organism that was isolated originally. Despite the potentiation of the antibiotics by the gamma globulin, as demonstrated by *in vivo* and *in vitro* studies, definite control of the infection was not achieved until the retroperitoneal abscess which took origin from the old lesion in the lumbar vertebra was drained. The rapid appearance of deafness subsequent to the use of one gram of ristocetin cannot be attributed to the ristocetin alone because two weeks prior to this the patient had been receiving vancomycin and erythromycin. However, the time sequence was suggestive since within twenty-four hours after one injection of ristocetin the patient's hearing began to diminish, and within several days he was totally deaf. The suppressive effect of the chemotherapy and gamma globulin on the infection is illustrated by the fact that the blood cultures were positive only when the medication was stopped and the abscess did not begin to drain until the chemotherapy was discontinued.

This case emphasizes the fact that antibiotics and gamma globulin alone will not be effective in all situations.

Case 3. The patient was a white man, fifty-three years old, who in June of 1956 had had severe gastro-enteritis and diarrhea due to *Salmonella typhimurium* which responded to the vigorous administration of fluids and chloramphenicol given in a dosage of 2 grams a day for nineteen days. In August 1956 severe backache developed, and roentgenograms showed a destructive process involving the second and third lumbar vertebrae (Fig. 3-A). In mid-September 1956, culture of material aspirated from the lesion in the lumbar spine with a Turckell needle revealed a pure growth of *Salmonella typhimurium*. At this time a body cast was applied, and therapy was instituted with a combination of 1 gram of chloramphenicol and 1 gram of tetracycline given orally each day.

One month after this therapy was started, roentgenograms showed definite progression of the lesion. For this reason, a combination of chloramphenicol, streptomycin, and gamma globulin was begun on the following schedule: chloramphenicol, 1 gram a day given intravenously; streptomycin, 0.5 gram given intramuscularly twice a day; and gamma globulin, 20 milliliters given intramuscularly three times a week. This regimen was continued from November 16 to December 20, 1956. The patient was then maintained on gamma globulin, 10 milliliters given intramuscularly three

times a week, and chloramphenicol, 2 grams a day given orally. In August 1957 the patient noted blurring of vision, and examination by an ophthalmologist revealed optic neuritis and abnormal visual fields. All therapy was discontinued at that time except for multivitamin tablets. The patient's vision returned to normal during the ensuing four months.

Thus, the patient received a one-year course of chloramphenicol in a full oral dosage of 2 grams a day before the optic neuritis developed. There was no exacerbation of symptoms or fever after therapy was discontinued, and at the time of writing the patient was well except for a residual bilateral vestibular disturbance which was attributed to the streptomycin and manifested by a staggering gait. He subsequently was able to compensate for this without difficulty. Roentgenograms (Fig. 3-B) of his spine on May 6, 1959, indicated that the process had healed with fusion of the involved vertebrae. At no time did evidence of bone-marrow depression manifest itself. In this case treatment with a body cast and oral antibiotic therapy failed to arrest the process until gamma globulin was added to the therapeutic regimen.

Case 4. A fourteen-year-old white boy was admitted to the hospital on August 20, 1958, for study because of pain in the low-back region, fever, and a weight loss of fourteen pounds during the two months prior to admission. There had been no trauma to the back, no exposure to tuberculosis, and no urinary symptoms. At the age of seven years he was said to have had an infection of

Fig. 3-A

Fig. 3-B

Figs. 3-A and 3-B: Case 3. *Salmonella typhimurium* osteomyelitis of the lumbar spine.
Fig. 3-A: December 6, 1956. Note the destructive lesion involving the interspace between the second and third lumbar vertebrae with involvement of the contiguous bone surfaces.
Fig. 3-B: May 6, 1959. Note the collapse of the interspace, the restoration of normal bone architecture, and the apparent solid fusion between the second and third lumbar vertebrae after nearly three and one-half years.

his right ankle for which he was hospitalized, and about one year prior to the onset of his present illness he had had some swelling of his cervical lymph nodes which had regressed spontaneously.

Physical examination revealed a well developed, well nourished boy in no acute distress. The temperature was 99 degrees Fahrenheit, the pulse was 70, the respirations were 16 per minute, and the blood pressure was 126 systolic, 76 diastolic. The physical examination was completely within normal limits except for definite tenderness over the area of the fourth lumbar vertebra. Roentgenographic examination of the chest was negative, but the spine was found to show narrowing of the fourth lumbar intervertebral disc space associated with destructive changes in the anterior and inferior aspect of the fourth lumbar body. It was the impression of the roentgenologist that the lesion was due to brucellosis or to other pyogenic infection.

The laboratory studies were as follows: the hemoglobin was 9.3 grams per 100 milliliters; the white-cell count 11,650, with 76 per cent segmented and 4 per cent non-segmented polymorphonuclear leukocytes, 3 per cent eosinophils, and 17 per cent lymphocytes. The erythrocyte sedimentation rate (Westergren) was 38 millimeters per hour. Urinalysis, including a microscopic examination of the sediment, was normal. Agglutination studies for typhoid and brucellosis were normal. The Wassermann test was negative. The serum proteins were 8 grams per 100 milliliters;

the albumin was 4.4 grams, and the globulin was 3.6 grams. There was no Bence Jones protein in the urine. Skin tests and complement-fixation studies for histoplasmosis and blastomycosis were negative.

Biopsy of the affected area was done under fluoroscopic control. Culture of the biopsy material was negative, and the sections were reported as consisting of spicules of bone, fragments of bone marrow, striated skeletal muscle, and fibro-adipose tissue with hemorrhage, with no tumor cells present.

The patient was placed in a complete body cast and discharged to be observed further, since a definite diagnosis had not been established. He was readmitted to the hospital on October 14, 1958, for further study because he continued to be febrile, and at this time roentgenograms of the lumbar region (Fig. 4-A) revealed that narrowing of the fourth disc space had increased slightly, with what appeared to be more destruction of the anterior and inferior part of the body of the fourth lumbar vertebra and early involvement of the body of the fifth lumbar vertebra with periosteal new-bone formation on its anterior aspect. The physical examination was essentially unchanged. Laboratory studies showed a hemoglobin of 11.3 grams per 100 milliliters, a white-cell count of 9,900, with 70 per cent polymorphonuclear leukocytes, with segmented neutrophils, 4 per cent eosinophils, 23 per

FIG. 4-A

FIG. 4-B

FIG. 4-C

Figs. 4-A through 4-C: Case 4. Rapid healing of a probable pyogenic arthritis in a boy fourteen years old.

Fig. 4-A: On October 14, 1958, four months after the onset of symptoms, the roentgenogram shows narrowing of the interspace, extensive involvement of the anterior and inferior portion of the body of the fourth lumbar vertebra, and early involvement of the superior portion of the body of the fifth lumbar vertebra.

Fig. 4-B: January 12, 1959. Seven months after the onset of symptoms and three months after therapy was started. Note the healing.

Fig. 4-C: May 1, 1959, eleven months after the onset of symptoms. The roentgenogram shows almost complete restoration of the normal bone architecture except for slight residual sclerosis. The interspace is narrow.

cent lymphocytes, and 3 per cent monocytes. The sedimentation rate (Westergren) was 43 millimeters in one hour. The electrophoretic pattern of the serum was normal.

Owing to the fact that on the roentgenogram the lesion appeared to be progressing, it was decided to treat the patient empirically for osteomyelitis of the spine. On October 14, 1958, the following program was instituted: gamma globulin, 20 milliliters initially and 10 milliliters given intramuscularly three times a week, and chloramphenicol, 0.5 gram given orally four times a day. The program was continued for twelve days in the hospital, and then the patient was discharged for out-patient care. The gamma globulin was given on an out-patient basis three times a week for seven months, and the chloramphenicol was continued to July 1959 (the time of writing). On this program the patient was asymptomatic and was without a body cast.

Roentgenograms of the spine on January 12, 1959, showed evidence of healing three months after therapy was started (Fig. 4-B), and by May 1, 1959, normal bone architecture was restored except for some sclerosis and narrowing of the interspace (Fig. 4-C).

It is unfortunate that we were unable to make a bacteriological diagnosis, but this case is included because the progression of the disease, which appeared to continue for six months despite rest and orally administered antibiotics, seemed to stop when the combination of drugs was begun, and rapid healing is evident on the roentgenogram (Fig. 4-C).

CASE 5. The patient was a white man, fifty-five years old, who injured his left shoulder in an

automobile accident in November 1957. Following surgical repair of a rupture of the rotator cuff of the shoulder which was done in April 1958, a wound infection developed due to staphylococci which were sensitive to erythromycin and chloramphenicol but resistant to penicillin. One week after the operation a staphylococcal pneumonia developed which responded to therapy with erythromycin over a period of approximately one month. He never regained his strength after this hospitalization, and in August 1958 began to note a severe pain along the lower aspect of his ribs on the left side. The pain was particularly severe with certain movements. He consulted his physician who found a tender area over the body of the ninth thoracic vertebra. Roentgenographic studies of this part of the spine revealed a destructive process in the body of the ninth thoracic vertebra and a soft-tissue shadow which was assumed to represent a perispinous abscess (Figs. 5-A and 5-B). Aspiration of this abscess for diagnostic purposes was not considered advisable by the orthopaedic consultant so therapy was begun on the assumption that this was metastatic staphylococcal osteomyelitis which was seeded at the time of the wound infection and staphylococcal pneumonia. A body cast was applied but it caused so much discomfort that it was removed.

Therapy with antibiotics and gamma globulin was instituted on August 16, 1958, as follows: 20 milliliters of gamma globulin given intramuscularly immediately and 10 milliliters given intramuscularly every other day; chloramphenicol, 2 grams in 600 milliliters of saline solution given intravenously every day; and streptomycin, 0.5 given immediately every eight hours. On August 23 the dosage of chloramphenicol was reduced to 1.5 gram given intravenously every day; and the streptomycin was reduced to 0.5 gram given intramuscularly twice a day. On September 2, 1958,

FIG. 5-A

FIG. 5-B

Figs. 5-A through 5-D: Case 5. Staphylococcal osteomyelitis of the ninth thoracic vertebra.
Figs. 5-A and 5-B: August 1958, shortly after the onset of symptoms referable to the thoracic spine. The anteroposterior view shows a shadow suggesting a perispinous abscess. The lateral view shows narrowing of the interspace and a destructive lesion in the superior portion of the body of the ninth thoracic vertebra.

the chloramphenicol given intravenously was discontinued but the daily dosage of 2 grams of chloramphenicol by mouth was continued. The patient was essentially asymptomatic when discharged on September 9, 1958, and was followed on an out-patient basis. He was taking 2 grams of chloramphenicol a day at the time of writing.

Within twenty-four hours of the institution of the combined medication there was definite improvement in the symptoms, and within four days the pain had almost disappeared. After discharge from the hospital treatment was continued as follows: chloramphenicol, 0.5 gram given by mouth four times a day, and gamma globulin, 10 cubic centimeters given intramuscularly three times a week from October 1958 through January 1959. The administration of gamma globulin was decreased to twice a week in January 1959, and to once a week in March 1959; it was discontinued in September 1959. The patient continued to take 2 grams of chloramphenicol a day by mouth. The sedimentation rate dropped from an initial value of 40 millimeters per hour in August 1958, a month before discharge, to 9 millimeters per hour in May 1959. The patient's clinical status, blood studies, and vision have remained excellent.

The significant laboratory studies revealed the following data: Bence Jones protein was ab-

sent from the urine; skin tests for a fungus and complement-fixation tests were within normal limits, and a second-strength Mantoux test for tuberculosis was negative; the serum albumin was 4 grams per 100 milliliters; and the globulin was 2 grams per 100 milliliters. Serial roentgenograms (Figs. 5-C and 5-D) of the spine showed progressive healing with further narrowing of the involved interspace. Electrophoretic patterns of the serum were normal before therapy.

This case of presumed staphylococcal osteomyelitis of the body of the ninth thoracic vertebra showed almost immediate response to the institution of therapy with chloramphenicol, gamma globulin, and streptomycin. The plan was to continue therapy for fifteen months and then to discontinue it and to observe the lesion carefully. If exacerbations occur, maintenance therapy over several more years will be instituted.

CASE 6. A white woman, sixty-one years old, with mild diabetes, first noted pain between the scapulae in August 1956. There was progressive increase of the pain until coughing and movement would cause it to radiate across the back over the shoulders and down over the epigastrium. There was also tenderness over the mid-thoracic spine. In April 1957 roentgenograms revealed a destructive process involving the fifth and sixth thoracic vertebrae (Fig. 6-A). Surgical consultation was obtained at this time, and it was believed that a biopsy for diagnostic purposes was not justified because of the location of the lesion and the danger that would be entailed by surgery in this area.

FIG. 5-C

FIG. 5-D

Fig. 5-C: May 3, 1959, nine months after the beginning of treatment. Note the further narrowing of the interspace, healing of the lesion in the body of the ninth thoracic vertebra, and the formation of bone spurs at the margins of the interspace.

Fig. 5-D: On September 1, 1959, the roentgenogram shows bone bridges across the involved interspace and a decrease in the perispinous soft-tissue swelling.

Diagnostic studies which included roentgenograms of the stomach, colon, and kidneys, the testing for Bence Jones protein in the urine, skin tests for fungus, and complement-fixation tests, were all normal. Laboratory studies showed that the hemoglobin was 10 grams, the white-cell count was 7,400 with 72 per cent polymorphonuclear leukocytes, 25 per cent lymphocytes, and 3 per cent monocytes, the sedimentation rate was 43 millimeters per hour, the serum albumin was 3.3 grams per 100 milliliters, the serum globulin was 3.3 grams per 100 milliliters, the alkaline phosphatase was 8 King-Armstrong units, the non-protein nitrogen was 44 milligrams per 100 milliliters, the second-strength Mantoux test was negative, agglutination tests for typhoid organisms and brucellosis were negative, and three blood cultures were negative. Repeated urinalyses showed clumps of white blood cells but no albumin. A urine concentration test showed a fixed specific gravity, and urine cultures showed *Proteus vulgaris* and *Escherichia coli*. The diagnosis of chronic pyelonephritis and mild diabetes was considered to be established, but the cause of the lesion in the spine was not established; a malignant tumor of the spine was suspected. The patient was given medication as follows: tetracycline, 1 gram a day on February 9 and 10; chloramphenicol, 1 gram a

FIG. 6-A

FIG. 6-B

Figs. 6-A and 6-B: Case 6. *Escherichia coli* osteomyelitis of the thoracic vertebrae.

Fig. 6-A: April 4, 1957, eight months after the onset of symptoms. The lateral view shows erosion of the contiguous portions of the bodies of the fifth and sixth thoracic vertebrae and destruction of the anterior half of the intervertebral space.

Fig. 6-B: January 25, 1958, seventeen months after the onset of symptoms and seven months after therapy with antibiotics and gamma globulin was begun. The lateral view shows healing with collapse at the involved vertebral bodies and solid interbody fusion.

day from February 10 through 15; tetracycline, 1 gram a day from April 19 through 22; penicillin, 1,600,000 units a day from April 22 through 24; tetracycline, 1.5 grams a day from April 22 through 28, and penicillin, 1,600,000 units a day from April 24 through 28, 1957.

The patient was discharged for observation as an out-patient on April 29, 1957, and told to take 1 gram of tetracycline a day and penicillin V, 1,600,000 units a day. Her backache continued to be severe and she noted no improvement in symptoms. She was therefore readmitted to the hospital and seen by me on June 21, 1957. Studies for Bence Jones protein in the urine, the Mantoux test, and roentgenograms of the gastro-intestinal tract again were negative. The sedimentation rate was 32 millimeters per hour. Additional history obtained at this time revealed that in April 1956 the patient had suffered an acute urinary-tract infection with high fever and prostration. She had been treated at home and responded to "antibiotics". In view of this, the assumption was made that a bacteremia had occurred and seeded the thoracic spine, probably with *Escherichia coli*. Therefore, therapy with gamma globulin, chloramphenicol, and streptomycin was given as follows: chloramphenicol, 2 grams a day given intravenously from June 23 through July 5; streptomycin, 0.5 gram given intramuscularly three times a day from June 23 through July 2; gamma globulin, 20 milliliters given intramuscularly immediately and 10 cubic centimeters every other day from June 23 through July 5, 1957.

The patient was then discharged from the hospital and treated as an out-patient, receiving chloramphenicol, 0.5 gram percutaneously four times a day from July 5 through 22, and gamma globulin, 10 cubic centimeters every other day from July 5 through 22, which was then reduced to 10 cubic centimeters once a week until December 2, 1957.

There was subjective improvement within forty-eight hours after the start of the combination of therapeutic agents of chloramphenicol, streptomycin, and gamma globulin, and by the time of discharge the patient was essentially free of symptoms. Treatment was discontinued on December 2, 1957, because the patient had numbness in the feet and ankles and in the finger tips of both hands. The peripheral neuritis gradually cleared over the ensuing twelve-month period during which time the patient received thiamine and ascorbic acid. She became asymptomatic, and the only residual effects of the osteomyelitis were the loss of three-fourths of an inch in height and some ataxia which was considered attributable to the streptomycin therapy. Blood studies remained normal during the entire course of therapy as did the patient's vision. The roentgenograms showed slow but steady improvement (Fig. 6-B). The patient received, in all, a total of approximately 320 grams of chloramphenicol and 350 milliliters of gamma globulin.

The most striking feature of this case was the rapid subjective improvement

FIG. 7-A

FIG. 7-B

Fig. 7-A: Case 7. Roentgenogram made on April 22, 1957, before operation for a herniated intervertebral disc between the fourth and fifth lumbar vertebrae.

Fig. 7-B: Roentgenogram made on June 10, 1958, shows bone bridging that suggests bone involvement after the operation.

after the institution of the combination of therapeutic agents. Unfortunately, the diagnosis was not established, but it was believed that the clinical response substantiated the impression that this was osteomyelitis of the thoracic spine caused by *Escherichia coli* or some other organism susceptible to chloramphenicol.

CASE 7. The patient was a white woman, forty-four years old, who was operated on for a herniated intervertebral disc on May 2, 1957 (Fig. 7-A). The wound opened and began to drain four days after operation. Drainage continued for twenty-eight days despite daily therapy with 600,000 units of penicillin given intramuscularly twice a day; chloramphenicol, 1 gram taken by mouth daily; and erythromycin, 1 gram taken by mouth daily. Cultures grew *Staphylococcus aureus* which was sensitive to 12 micrograms per milliliter of chloramphenicol, 0.75 microgram per milliliter of penicillin, and less than 0.38 microgram per milliliter of erythromycin.

On the twenty-eighth postoperative day the treatment with penicillin was intensified owing to the fact that paralysis of the patient's left foot developed. Twenty million units of penicillin was given intravenously every day in 500 milliliters of 5 per cent dextrose in water, and 600,000 units of aqueous penicillin was administered intramuscularly every six hours. Each infusion of penicillin was preceded by 0.5 gram of benamid given by mouth. This was continued for three days, after which time *Staphylococcus aureus* was still present in the drainage, with no change in the sensitivity studies. Therefore, since the high dosage of penicillin alone had not been effective it was decided to add gamma globulin to the therapeutic program. She was given 20 milliliters of gamma globulin intramuscularly initially and 10 milliliters each day. There was a definite decrease in drainage within twenty-four hours after the gamma globulin was started. Two wound cultures just before therapy with gamma globulin was initiated grew abundant colonies of *Staphylococcus aureus*. Twenty-four hours after the gamma globulin was started the wound, which by this time already had very little drainage, cultured only occasional colonies of coagulase-negative staphylococci. Forty-eight hours after the gamma globulin had been added, only *Escherichia coli* were cultured from the edges of the wound, and no further staphylococci were cultured despite daily attempts. The intensive therapy with the combination of gamma globulin and penicillin was continued for fourteen days, and at the end of this time, because of the excellent clinical status of the patient and the fairly acute onset of the process, therapy was discontinued. The patient was discharged on July 3, 1957, completely asymptomatic and has been well ever since with no recurrence of infection or pain. Follow-up roentgenograms (Fig. 7-B) showed eventual bone bridging of the area, which suggests bone involvement after the operation.

In this case a presumably adequate trial of penicillin and chloramphenicol

FIG. 8-A

FIG. 8-B

FIG. 8-C

Figs. 8-A through 8-C: Case 8. A lateral roentgenogram made on June 3, 1953, shows the disc space three months after the initial surgery for removal of a herniated intervertebral disc at the fifth lumbar-first sacral level.

Fig. 8-B: The roentgenogram made on November 11, 1955, after the injection of lipiodol in the sinus shows the tract going into the sacrum (this area was the area then saucerized).

Fig. 8-C: The lateral roentgenogram made on January 5, 1960, shows slight irregularity of the bodies of the first and second sacral vertebrae and moderately increased density of the bone in the region of the lumbosacral joint.

given before the use of gamma globulin resulted in no demonstrable response. When gamma globulin was added to the penicillin therapy, negative cultures were obtained within forty-eight hours, and the patient was asymptomatic afterward. These follow-up roentgenograms (Fig. 7-B) suggested that this infection was a true osteomyelitis of the spine and deep-seated wound infection complicating an operation for the removal of a ruptured intervertebral disc. Even though the organism was sensitive to penicillin, which was therefore the drug of choice and was given in massive doses, the gamma globulin apparently was necessary in order to control the infection. Although it must be admitted that this wound might have healed without this vigorous therapy, this treatment may have prevented the situation which developed in Case 8.

CASE 8. The patient was a woman, thirty-three years old, who had had a hard shaking chill on March 14, 1953, eleven days after operation for the removal of a herniated intervertebral disc at the fifth lumbar-first sacral level (Fig. 8-A).

She continued to have intermittent chills and fever until March 23, when the wound opened spontaneously and drained 100 milliliters of frank pus. *Staphylococcus aureus*, sensitive to erythromycin but resistant to penicillin, was cultured from the wound.

She had received 300,000 units of penicillin intramuscularly twice a day and 1 gram of streptomycin intramuscularly twice a day from March 13 through 21, and 1.2 grams of erythromycin by mouth every day from March 8 to March 10 and then 0.8 gram by mouth every day from April 10 to 25 1953. Hot packs were applied to the patient's back, and varidase was instilled into the wound. The wound continued to drain, and the cultures remained positive despite the therapy, but the patient was comfortable so she was discharged.

Intermittent drainage from the wound in the back, preceded by malaise and low-grade fever, continued until July 21, 1955, at which time she was readmitted to the hospital for excision of the sinus tract.

At operation, a sinus was found that led directly to the left over the posterosuperior spine of the ilium and then downward and back toward the sacrum. The sinus was excised in its entirety, and the wound was closed with sutures of chromic catgut in the deep tissues and silk in the skin. The patient was given 0.8 gram of erythromycin by mouth every day, and the wound healed. The patient was discharged on August 5, 1955. Several weeks after discharge from the hospital, intermittent fever and drainage from the wound recurred and continued until November 17, 1955, when the patient was readmitted to the hospital for further surgery (Fig. 8-B).

At this procedure a sinus was traced out into the gluteal muscles on the right and down to the greater sciatic notch; it also extended into the sacrum in the mid-line. The entire sinus was removed, and the sacrum was saucerized in the mid-line, exposing the spinal canal at the first and second sacral levels, where there was questionable abscess formation. The wound was closed with a drain left in place. The drain was removed ten days later. The patient's general condition improved greatly, but at the time of discharge on December 12, 1955, there was still drainage from the wound which had continued despite 1 gram of erythromycin a day taken by mouth during the entire hospitalization. After discharge from the hospital, intermittent drainage as well as episodes of fever and malaise still continued to July 1957, and the abscesses were drained about every month in her physician's office.

When first seen by me in July 1957 the patient stated that she had not felt really well since the beginning of the infection four years previously. Culture of the sinus revealed *Staphylococcus aureus*, sensitive to 12 micrograms per milliliter of chloramphenicol and 1.5 micrograms per milliliter of erythromycin. Since the patient refused an additional surgical procedure, a combination of chloramphenicol and gamma globulin was started as follows: on July 8, 10, 12, and 15 she was given 10 cubic centimeters of gamma globulin intramuscularly while being maintained on 2 grams a day (0.5 gram four times a day) of chloramphenicol taken by mouth. The drainage stopped entirely during this period, and the patient became completely afebrile. She was continued on the chloramphenicol and 10 cubic centimeters of gamma globulin given intramuscularly three times a week from July until October 1957. A body cast which was applied at the end of July was worn for one year. In October 1957 peripheral neuritis developed with symptoms in both feet and ankles so the chloramphenicol was stopped. At this time the patient's vision was normal.

One week after the chloramphenicol was stopped the fever returned, and the patient noted some malaise. She then was started on propionyl erythromycin ester (ilosone), 0.5 gram four times a day, and within forty-eight hours she was completely afebrile. It was decided to withhold the gamma globulin to see whether the propionyl erythromycin ester alone would control the infection. This proved to be the case, and she was on propionyl erythromycin ester from then on. The cast was removed at the end of one year, and at the time of writing (July 1959) the patient was completely afebrile and asymptomatic and had had no drainage since the onset of treatment. A follow-up roentgenogram was made in January 1960 (Fig. 8-C).

The response of this patient was indeed satisfactory since she became completely well after four years of invalidism. Past experience with osteomyelitis of this type has convinced me that maintenance antibiotic therapy, as long as it is well tolerated, is one way of preventing recurrences, and this is the plan being followed at present. The length of time that this should be continued has yet to be determined.

DISCUSSION

Osteomyelitis of the spine has been the subject of many excellent reports in the literature but these will not be reviewed in detail here [2, 3, 5, 6, 7, 9, 8, 10, 11, 14, 16, 17]. A survey of this literature reveals that cases similar to those described here are not excessively rare, and that in many instances they respond to immobilization, surgical drainage, and specific chemotherapy without the addition of gamma globulin. On the other hand, many of the cases reported, particularly in the older literature, ended fatally. The more recent articles, especially those dealing with infections of

an intervertebral space following the removal of lumbar intervertebral discs, emphasize the importance of the direct surgical approach for diagnosis and treatment of vertebral lesions [8, 14].

The importance of adequate drainage in any localized infection is well recognized, but it may prove difficult to establish in these deep-seated infections, for one reason or another. The favorable response of the patients in this series to therapy with combinations of antibiotics and gamma globulin suggests that this form of therapy may have value both as an alternative to surgical treatment, if it is not feasible, and as an adjunct to surgical drainage in resistant bone and joint infections.

The mechanism or mechanisms by which gamma globulin appears to potentiate the action of antibiotics is as yet unknown, and I have so far not been able to demonstrate consistently the *in vitro* potentiation which was found in Case 2 of this report [4, 12, 13, 15]. However, the clinical response obtained by the addition of gamma globulin to antibiotics should emphasize the fact that further study of host factors in the control of infection may prove fruitful as a means of finding better ways to control stubborn and indolent infections. Electrophoretic studies done on all patients gave patterns within normal limits, so it seems likely that the effect of the globulin therapy represents more than a quantitative replacement of depleted gamma globulin. The principal reason for this preliminary report is to point out that some patients with severe life-threatening infections who do not respond to conventional treatment may be benefited by high dosages of gamma globulin in addition to appropriate antibiotics. When the mechanisms of this phenomenon are understood, and optimum dosage forms and modes of administration are worked out, a more general use of the type of therapy based on the principle of augmentation of host factors may conceivably be possible.

SUMMARY

Eight cases of pyogenic osteomyelitis of the spine are presented in which a satisfactory clinical response was obtained with combinations of antibiotics with human gamma globulin. It is suggested that certain patients with this disease who are not responding to conventional methods of therapy may benefit from the administration of combinations of antibiotics and gamma globulin, and that prolonged maintenance therapy with antibiotics may be necessary to prevent recurrence.

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REFERENCES

1. ABBOUD, F. M., and WAISBREN, B. A.: Correlation between in Vitro Studies and Response to Antibiotic Therapy in Staphylococcic Bacteremia. A.M.A. Arch. Int. Med., **104**: 226–233, 1959.
2. BUTTERWORTH, R. D., and CARPENTER, E. B.: Pyogenic Osteomyelitis of the Cervical Spine with Quadriplegia Secondary to Cord Pressure. Southern Med. J., **42**: 561-564, 1949.
3. DONATI: Cited by Lazarus [10].
4. FISHER, M. W.: Synergism Between Human Gamma Globulin and Chloramphenicol in the Treatment of Bacterial Infections. Antibiot. and Chemother., **7**: 315–332, 1957.
5. GURI, J. P.: Pyogenic Osteomyelitis of the Spine. Differential Diagnosis Through Clinical and Roentgenographic Observations. J. Bone and Joint Surg., **28**: 29–39, Jan. 1946.
6. HATCH, E. S.: Acute Osteomyelitis of the Spine. Report of Case with Recovery. Review of the Literature. New Orleans Med. and Surg. J., **83**: 861–874, 1931.
7. JANSEY, FELIX, and ANTHONY, J. E., JR.: Staphylococcal Septicemic Spondylitis, with Bilateral Costotransversectomy. Northwestern Univ. Med. Sch. Bull., **31**: 114–119, 1957.
8. JOHNSON, R. W. JR.; HILLMAN, J. W.; and SOUTHWICK, W. O.: The Importance of Direct Surgical Attack upon Lesions of the Vertebral Bodies, Particularly in Pott's Disease. J. Bone and Joint Surg., **35-A**: 17–24, Jan. 1953.
9. KULOWSKI, JACOB: Pyogenic Osteomyelitis of the Spine. An Analysis and Discussion of 102 Cases. J. Bone and Joint Surg., **18**: 343–364, Apr. 1936.
10. LAZARUS, J. A.: Osteomyelitis of the Vertebrae with Report of Two Cases Simulating Perinephritic Abscess. Am. J. Surg., **15**: 82–87, 1932.

11. LEIGH, T. F.; KELLY, R. P.; and WEENS, H. S.: Spinal Osteomyelitis Associated with Urinary Tract Infections. Radiology, **65**: 334–342, 1955.
12. REEDY, R. J.; OSWALD, E. J.; and WRIGHT, W. W.: The Effect of Gamma Globulin and Specific Antiserum Combined with Antibiotics in Experimental Infections in Mice. *In* Antibiotics Annual 1957–1958, pp. 581–584. New York, Medical Encyclopedia, Inc., 1958.
13. SCHONHOLTZ, G. J.; BORGIA, C. A.; and RITCHEY, S. J.: The Combined Use of Gamma Globulin and Broad-Spectrum Antibiotics in the Treatment of Osteomyelitis. *In* Antibiotics Annual 1958–1959, pp. 635–642. New York, Medical Encyclopedia, Inc., 1959.
14. THIBODEAU, A. A., and MALOY, J. K.: Closed-Space Infection Following Removal of Lumbar Intervertebral Disc. J. Bone and Joint Surg., **40-A**: 717, June 1958.
15. WAISBREN, B. A.: The Treatment of Bacterial Infections with Combination of Antibiotics and Gamma Globulin. Antibiot. and Chemother., **7**: 322–333, 1957.
16. WEAR, J. E.; BAYLIN, G. J.; and MARTIN, T. L.: Pyogenic Osteomyelitis of the Spine. Am. J. Roentgenol., **67**: 90–94, 1952.
17. WILENSKY, A. O.: Osteomyelitis of the Vertebrae. Ann. Surg., **89**: 561–570, 731–747, 1929.

Hematogenous Pyogenic Vertebral Osteomyelitis*

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One hundred patients with a diagnosis of vertebral osteomyelitis were treated at the New York Orthopaedic Hospital, Columbia-Presbyterian Medical Center, during the past twenty-five years. Their records were analyzed, and in forty patients the diagnosis was considered to be hematogenous pyogenic osteomyelitis. The remaining sixty patients were excluded for a variety of reasons, the most common one being postoperative infection after disc surgery (Table I).

Of the forty cases of hematogenous vertebral osteomyelitis that were analyzed, thirty were diagnosed and treated during the era of antibiotics (since 1943). There were twenty-four male and sixteen female patients. Their ages ranged from three and one-half to seventy-eight years. Five patients were non-Caucasians. Twenty-five of the forty patients were ward patients and fifteen were private patients.

CLINICAL PICTURE

History

In each patient the presenting complaint was back pain, frequently with nerve-root pain. The location and distribution of pain were determined by the vertebral segment involved. The onset of pain was abrupt or gradual, but usually gradual. The average time from first symptom to hospitalization was eight to ten weeks, which illustrates the insidious nature of this disease.

There was a paucity of systemic manifestations. Half of the patients were unaware of fever prior to admission. On admission two-thirds of the patients had temperatures below 100 degrees Fahrenheit, and only two had temperatures above 102 degrees. On the other hand, the local and radiating pain, which often

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 28, 1960.

TABLE I

PATIENTS EXCLUDED AND REASON

Reason		No. of Patients
Infection after disc surgery		25
Other diagnoses		11
Tuberculosis	7	
Scheuermann's disease	2	
Charcot spine	1	
Tumor	1	
Secondary to local soft-tissue infection, such as: postoperative abdominoperoneal resection, adrenalectomy, and sympathectomy		9
Manifestation of generalized osteomyelitis		6
Primary focus, sacral or sacro-iliac		5
Fungal infections		3
Actinomycosis	2	
Blastomycosis	1	
After lumbar puncture		1
	Total	60

TABLE II

ANTECEDENT EVENTS IN FORTY CASES OF HEMATOGENOUS PYOGENIC OSTEOMYELITIS

Antecedent Event		No. of Patients
Genito-urinary procedures		8
Prostatectomy	4	
Instrumentation	1	
Prostatic massage	1	
Obstructive pyelitis	1	
Vaginoplasty	1	
Furunculosis		7
Neck	5	
Iliac crest	1	
Arms	1	
Trauma		6
Upper respiratory infection		5
Septic arthritis (knee)		1
Phlebitis with pulmonary infarction		1
None		12

suggested a mechanical derangement of the spine, tended to overshadow the systemic reaction. The severity of the pain was dramatic and incapacitating in many instances.

Inquiry into the past medical history revealed two salient features. One was the high incidence of diabetes mellitus. There were ten diabetics in this group, making an incidence of 25 per cent. When only the patients over thirty-five years of age were considered the incidence was 35 per cent. Two significant antecedent events were noted in many patients: (1) some genito-urinary procedure and (2) furunculosis (Table II).

We do not believe that trauma and physical injury were important factors; they merely drew attention to the back. This frequently led the examiners to suspect a mechanical derangement of the spine erroneously. In twelve cases there was no apparent precipitating cause.

Physical Findings

The principal physical findings were painful muscle spasm and limited motion of the spine. Occasionally, an angular kyphos or signs of psoas irritation were

TABLE III

INITIAL NEUROLOGICAL FINDINGS IN FORTY CASES OF HEMATOGENOUS PYOGENIC OSTEOMYELITIS

Neurological Finding	No. of Patients
Normal findings	23
Borderline findings	11
Atrophy, weakness, or sensory loss	4
Bowel and bladder dysfunction	1
Transverse myelitis	1

detected. Positive neurological findings were often borderline or absent (Table III).

Laboratory Findings

The outstanding laboratory finding was the elevated erythrocyte sedimentation rate with a relatively low leukocyte count. The average sedimentation rate done shortly after admission was 87 millimeters per hour (Westergren); 85 per cent of the determinations were over 40 millimeters per hour. The admission leukocyte count was normal (5,000–10,000 cells per cubic millimeter) in 50 per cent of cases; in only five patients were the counts over 15,000. In other words, 88 per cent of the counts were under 15,000. Thus, there was an apparent disparity in the response to the infection as manifested by the sedimentation rate and leukocyte count.

The tuberculin skin test was positive in eleven patients, negative in fourteen, and undetermined in fifteen. This test was helpful in making a diagnosis of pyogenic osteomyelitis only when negative. Skin tests for brucellosis and various pathogenic fungi were occasionally performed; they were of limited value in this series.

Roentgenographic Findings

The roentgenographic findings corresponded with the classic description of pyogenic osteomyelitis in the literature: there was narrowing of the intervertebral disc space with subsequent bone destruction followed by early proliferation of bone. The roentgenographic findings within a month of onset of the disease in most instances were minimum. Furthermore, it was necessary to resort to laminagraphy to demonstrate the lesion in several patients in whom there was a strong clinical suspicion of osteomyelitis of the spine; this technique should probably be used more often.

Paravertebral masses were demonstrated roentgenographically in thirteen patients.

BACTERIOLOGY

Of the patients included for study, in fourteen a positive bacterial culture was obtained from the vertebral lesion, and in five other patients the diagnosis was made on the basis of histology. In seven patients with roentgenographic and clinical evidence of vertebral infection, one or more positive blood cultures were obtained. Thus, 65 per cent of the patients studied had documentary evidence of pyogenic infection. The remaining patients had typical clinical, roentgenographic, and laboratory findings of pyogenic osteomyelitis.

The organism was identified in twenty-two patients. The cultures were obtained by open biopsy, closed biopsy with a Craig trocar, or blood culture. *Staphylococcus aureus* was obtained in the majority of patients. In four cases, however, *Pseudomonas aeruginosa* (*Pseudomonas pyocyanea*) was cultured. In each of these four patients there was a history of some genito-urinary procedure

(Table IV). In recent years closed biopsy has proved valuable. In this series of ten attempted closed biopsies, eight were diagnostic—five by positive culture, and three by histological examination of aspirated tissue.

LEVEL OF VERTEBRAL INVOLVEMENT

The location of the infection is significant both diagnostically and therapeutically. Chart I represents graphically the spinal levels of the lesions in this series, the nature of involvement, and the presence or absence of abscess forma-

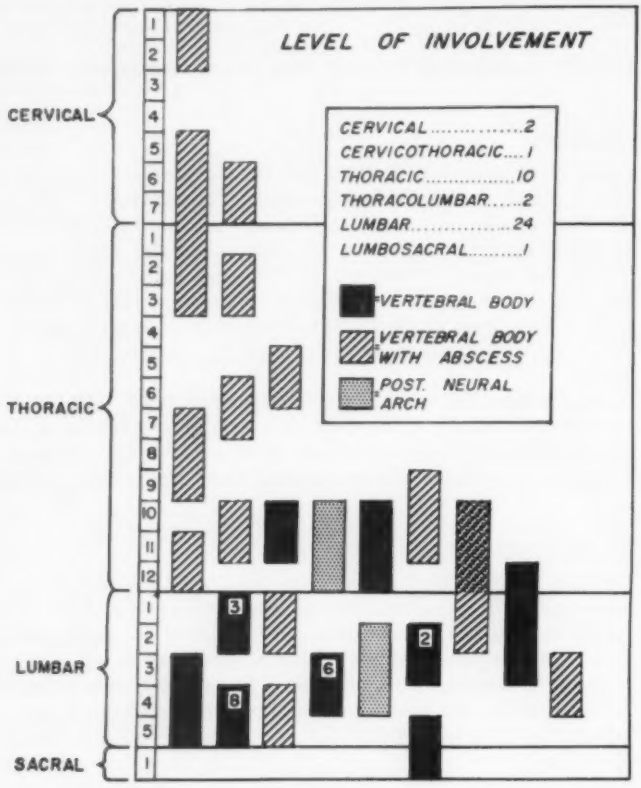

CHART 1

tion. It will be seen that the vertebral body is involved much more commonly than the posterior neural arch. Also of note is the finding that, although two-thirds of the infections involved the lumbar spine, only one-quarter of the paravertebral abscesses formed there—that is, abscess formation was much more likely in the cervicothoracic region. The vertebra most commonly affected was the fourth lumbar, followed in incidence by the third, fifth, and second lumbar.

TREATMENT

Twenty-seven of the forty patients were treated by absolute bedrest, often with additional plaster or brace immobilization. Eight patients underwent incision and drainage of abscesses (including costotransversectomy); most of these procedures were done during the preantibiotic era.

Laminectomy was performed on two patients having the erroneous diagnosis of epidural abscess. Both patients recovered with bedrest and immobilization.

FIG. 1-A

FIG. 1-B

Figs. 1-A through 1-D: J. S., a man sixty-one years old, with diabetes, was admitted on July 8, 1957, with low-back pain and fever with a history of an antecedent furuncle of the neck. The bacterial culture from the vertebral lesion was positive. Spontaneous fusion occurred, with complete remission of symptoms.

FIG. 1-C

FIG. 1-D

Fusion at level of infection was performed on only three patients. In one, fusion was performed ten years after onset for relief of pain due to localized osteoarthritis. The second patient treated by fusion recovered after a stormy course, at a rate comparable to the patients treated simply with body casts and bedrest. The third patient treated by fusion was one of our two fatalities. The other fatality also followed surgical intervention—an incision of a paravertebral abscess.

There were other features common to these two fatalities that are of interest. Both patients were older men (sixty-six and seventy-one years of age) with involvement of the thoracic vertebrae with an associated paraspinal abscess

TABLE IV

POSITIVE CULTURES AND ORGANISM IN TWENTY-TWO PATIENTS

	Vertebral Biopsy			No. of	No. of
	Open	Closed	Blood	Cultures	Patients
Staphylococcus aureus	6	4	8	18	14
Pseudomonas aeruginosa (*Ps. pyocyanea*)	2	1	2	5	4
Streptococcus viridans	1			1	1
Streptococcus pyogenes			1	1	1
Escherichia coli			1	1	1
Aerobacter aerogenes			1	1	1
Totals	9	5	13	27	22

TABLE V

LENGTH OF FOLLOW-UP IN FORTY CASES OF HEMATOGENOUS PYOGENIC OSTEOMYELITIS

Follow-up (*Years*)	No. of Cases
<1	8
1–5	16
6–10	5
11–15	5
16–20	3
21–25	1
(Deaths	2)

FIG. 2-A

FIG. 2-B

Figs. 2-A through 2-E: G. I., a man sixty-nine years old, was admitted on September 11, 1957, with a five-month history of low-back pain. The onset was one month after suprapubic prostatectomy. The diagnosis was made by histological examination of aspirated tissue. Progressive fusion was demonstrated on the roentgenograms, with complete recovery.

FIG. 2-C

FIG. 2-D

and septicemia. The cause of death in each patient was transverse myelitis. One death occurred during the era of antibiotics, the other before.

Three-fourths of our patients were treated during the past fifteen years. In addition to the treatment outlined, these patients received antibiotics in the manner that was considered appropriate at the time of treatment. We believe that bedrest and immobilization with a plaster jacket or brace are fundamental in treatment. The length of immobilization should be determined by individual response to treatment as evidenced by remission of pain, fever, sedimentation rate and until there is roentgenographic evidence of healing. The same criteria should be applied to the use of antibiotics, the principal adjunctive treatment in this disease. Selection of the particular antibiotic should be guided by the bacteriological sensitivities when available. The duration of antibiotic treatment should be dictated by the clinical response. No accurate figures as to the most effective antibiotic dosage schedule could be determined from our cases; no significant complications resulted from antibiotics.

FIG. 2-E

FOLLOW-UP

The follow-up was considered adequate on thirty patients, the average period of follow-up being seven and one-half years, and the longest twenty-five

years (Table V); two patients died, and eight were followed for less than one year.

The hospital stay averaged four months, excluding the data on three patients treated in the preantibiotic era who had multiple sinuses and required repeated admissions. Also excluded is a patient with bizarre symptoms who was hospitalized for three and one-half years in several hospitals under a variety of diagnoses. The average time required to return to work was twelve months from onset. Spontaneous interbody fusion was the rule in these patients, occurring in less than one year in most instances, and in two years in almost all other instances (Figs. 1-A through 1-D and 2-A through 2-E).

SUMMARY

Forty patients with hematogenous pyogenic vertebral osteomyelitis have been considered. The clinical picture has been presented, emphasizing the often subtle and subacute nature of the disease. The laboratory findings in many patients demonstrated a high sedimentation rate with a normal or slightly elevated leukocyte count. Frequently, the lesion was not demonstrable by roentgenogram early in the disease. Eventual spontaneous interbody fusion was the rule. Optimum treatment should include an accurate bacterial diagnosis followed by therapy with the appropriate antibiotic, bedrest, and immobilization. Despite the long morbidity there is minimum residual disability. This study has emphasized the beneficial results obtained by immobilization in comparison with those following operative intervention.

REFERENCES

1. Armstrong, J. R.: Lumbar Disc Lesions; Pathogenesis and Treatment of Low Back Pain and Sciatica, pp. 127–129. Edinburgh, E. & S. Livingstone, Ltd., 1952.
2. Craig, F. S.: Vertebral-Body Biopsy. J. Bone and Joint Surg., **38-A:** 93–102, Jan. 1956.
3. Guri, J. P.: Pyogenic Osteomyelitis of the Spine. Differential Diagnosis Through Clinical and Roentgenographic Observations. J. Bone and Joint Surg., **28:** 29–39, Jan. 1946.
4. Hatch, E. S.: Acute Osteomyelitis of the Spine. Report of a Case with Recovery. Review of Literature. New Orleans Med. and Surg. J., **83:** 861–874, 1931.
5. Kulowski, Jacob: Pyogenic Osteomyelitis of the Spine. An Analysis and Discussion of 102 Cases. J. Bone and Joint Surg., **18:** 343–364, Apr. 1936.
6. Smith, A. DeF.: A Benign Form of Osteomyelitis of the Spine. J. Am. Med. Assn., **101:** 335–337, 1933.
7. Steindler, Arthur: Post-Graduate Lectures on Orthopedic Diagnosis and Indications. Vol. 3, Section B: Osteomyelitis, pp. 408–433. Springfield, Illinois, Charles C. Thomas Co., 1952.

DISCUSSION

Dr. Robert W. Johnson, Jr., Baltimore, Maryland: The first two things that strike one are: (1) the relative infrequency of the condition—an average of less than two a year in such an active clinical center; and (2) the extreme importance of an early and accurate diagnosis and treatment for the few persons affected. Many members of our audience may go for years without seeing a case, but they should never forget to consider it in a differential diagnosis of back pain with or without nerve-root pain. It is too dangerous and painful a condition to fumble with, and we should all be indebted to the authors for re-emphasizing this disease entity and stressing the difficulty of its recognition. They have given us as accurate a description as possible and have outlined what I feel to be a very thorough and a sane method of attack and treatment.

Personally, I am inclined to be more radical in the surgical attack on the lesion for culture and diagnosis and also drainage, even in these days of antibiotics.

Perhaps I was influenced in this regard by my revered friend and mentor, the late Professor G. R. Girdlestone, of Oxford, who advised, even in preantibiotic days, the incision and drainage of any considerable paravertebral abscess in Pott's disease, as well as in more acute lesions of the vertebral bodies.

It is an extraordinary coincidence that in the November 1959 British number of The Journal there is an excellent article by Mr. A. M. Wiley and Professor Trueta from the same Oxford center entitled "The Vascular Anatomy of the Spine and its Relationship to Pyogenic Vertebral Osteomyelitis". They report nineteen cases in fifteen years, with clinical and bacteriological findings quite comparable to Dr. Garcia's and Dr. Grantham's. There was one death, one instance of paraplegia, and seventeen good recoveries, with two patients still having activity at the site of bone infection. In the same period there were only eighteen adults with acute hematogenous osteomyelitis in all the other bones of the body—an interesting comparative figure.

(Continued on page 520)

Bone Magnesium Content in Normal and Acidotic Rats*

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Although the presence of magnesium in bone salt has long been recognized [8], its chemical combination and its significance in terms of bone structure and metabolism remain obscure. Most authorities believe that magnesium occurs as a fortuitous surface contaminant rather than an integral part of the apatite lattice [9,12]. Excessively calcified, brittle bones have been observed in some instances of experimental magnesium deficiency. Blaxter, however, showed that

TABLE I

CHANGES IN BONE COMPOSITION IN ACIDOTIC RATS*

Group	Milliequivalents per Kilogram Wet Weight				Ratios		
	Ca	Mg	Na	$CO_3^=$	Na/Ca	$CO_3^=$/Ca	Mg/Ca
Normal (14 rats)	8,000	197	173	1,075	0.022	0.137	0.024
(S. E.) †	(313)	(9)	(6)	(45)	(0.002)	(0.003)	(0.002)
Acidotic (13 rats)	7,800	204	119	949	0.015	0.121	0.026
(S. E.) †	(165)	(6)	(7)	(32)	(0.001)	(0.002)	(0.001)
P †	>0.5	>0.5	<.01	<.05 >.02	<.01	<.01	<0.3

* After the production of acidosis, there is no change in the absolute content of bone magnesium or in the ratio of magnesium to calcium. In contrast, carbonate and sodium decrease in absolute amounts and in proportion to calcium.

† S. E. and P calculated according to Fisher's t test.

serum and total body magnesium can be very greatly reduced without affecting alkaline-phosphatase activity, bone growth, or the microscopic appearance of the epiphyses. He was able to demonstrate a shift of magnesium from bone to soft tissues in depleted animals, suggesting that skeletal reserves of this element may constitute a reservoir of some physiological importance. Similar inferences may be drawn from the experiments of Duckworth and Godden and of Orent, Kruse, and McCollum.

Hendricks and Hill and Neuman and Neuman stated that both sodium and magnesium are probably situated at the surface of bone-salt crystals. Logan and Taylor and Dallemagne and Melon postulated on the basis of solubility experiments that bone magnesium is combined with carbonate. Substantial amounts of carbonate are withdrawn from bone by the feeding of acid [10], by intraperitoneal dialysis against ammonium chloride [1], and by the production of metabolic acidosis with acetazolamide [2]. Bone sodium is simultaneously reduced. In the present study the magnesium content of bone from acidotic rats was compared with that of

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normal animals in order to assess the probability of an association between magnesium and carbonate in bone salt. Evidence is adduced that no such combination exists.

Acidosis was produced in adult male albino rats by the intraperitoneal injection of 0.09 molar ammonium chloride, the dosage being equal to 10 per cent of the body weight. After four hours an equal or slightly greater volume of peritoneal fluid was withdrawn by paracentesis. The rats were fasted for forty-eight hours before sacrifice. Samples included all of the long bones of each rat, dried and pulverized before aliquots were taken for analysis. Magnesium was measured by the Titan-yellow reaction of Orange and Rhein, calcium by titration of the oxalate with permanganate, sodium by internal standard flame photometry after separation from calcium [1], and carbonate by the microdiffusion technique of Conway adapted to bone.

Serum pH decreased from 7.33 to 7.20, and serum carbon dioxide (CO_2) from 26 to 21 milliequivalents per liter after the procedure[3]. Table I shows the data on bone. Calcium (Ca) did not decrease significantly. The ratios of sodium (Na) and carbonate (CO_3) to calcium diminished, as did the absolute amounts of these substances. Magnesium (Mg), however, showed no significant change either in absolute amount or in proportion to calcium. The changes in sodium and carbonate have been reported elsewhere, with the suggestion that the amount of carbonate liberated corresponds to the observed sodium decrement if sodium is presumed to be mobilized as sodium bicarbonate ($NaHCO_3$) [1]. The carbonate decrease amounts to 125 milliequivalents per kilogram or 12 per cent of the control value. If magnesium is present as carbonate, it is surprising that such a substantial carbonate loss is not accompanied by any change in magnesium.

It is also interesting that bone magnesium has consistently been found to decrease with age[12], whereas the reverse is true of carbonate. Two other anions, phosphate and citrate, are known to be present at the crystal surface. Each is trivalent and capable of combining simultaneously with magnesium and with surface calcium.

In contrast to the *in vitro* experiments just mentioned[6, 11], the present data suggest that bone magnesium is not present in combination with carbonate.

REFERENCES

1. Bergstrom, W. H.: The Relationship of Sodium and Potassium to Carbonate in Bone. J. Biol. Chem., **206:** 711–715, 1954.
2. Bergstrom, W. H.: The Participation of Bone in Total Body Sodium Metabolism in the Rat. J. Clin. Invest., **34:** 997–1004, 1955.
3. Bergstrom, W. H., and Wallace, W. M.: Bone as a Sodium and Potassium Reservoir. J. Clin. Invest., **33:** 867–873, 1954.
4. Blaxter, K. L.: *In* Ciba Foundation Symposium on Bone Structure and Metabolism. Edited by G. E. W. Wolstenholme and C. M. O'Connor. Boston, Little, Brown and Co., 1956.
5. Conway, E. J.: Microdiffusion Analysis and Volumetric Error. Ed. 3. London, Crosby Lockwood and Son, 1951.
6. Dallemagne, M. J., and Melon, J.: L'état chimique du magnésium et du sodium des sels osseux. Arch. Internat. Physiol., **58:** 188–200, 1950.
7. Duckworth, John, and Godden, William: The Lability of Skeletal Magnesium Reserve. The Influence of Rates of Bone Growth. Biochem. J., **35:** 816–823, 1941.
8. Gabriel, S.: Chemische Untersuchungen über die Mineralstoffe der Knochen and Zähne. Zeitschr. f. Physiol. Chem., **18:** 257–303, 1894.
9. Hendricks, S. B., and Hill, W. L.: The Nature of Bone and Phosphate Rock. Proc. Nat. Acad. Sciences, **36:** 731–737, 1950.
10. Irving, Laurence, and Chute, A. L.: The Participation of Carbonates of Bone in the Neutralization of Ingested Acid. J. Cell. and Comp. Physiol., **2:** 157–176, 1932.
11. Logan, M. A., and Taylor, H. L.: The Solubility of Bone Salt. The Partial Solution of Bone and Carbonate-Containing Calcium Phosphate Precipitates. J. Biol. Chem., **125:** 391–397, 1938.
12. Neuman, W. F., and Neuman, M. W.: The Nature of the Mineral Phase of Bone. Chem. Revs., **53:** 1–45, 1953.
13. Orange, Michael, and Rhein, H. C.: Microestimation of Magnesium in Body Fluids. J. Biol. Chem., **189:** 379–386, 1951.
14. Orent, E. R.; Kruse, H. D.; and McCollum, E. V.: Studies on Magnesium Deficiency in Animals. Chemical Changes in Bone, with Associated Blood Changes, Resulting from Magnesium Deprivation. J. Biol. Chem., **106:** 573–593, 1934.

A Study of Experimental Trauma and Attempts to Stimulate Growth of the Lower Femoral Epiphysis in Rabbits—III*

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This is the third report of a continuous series[4,7] of experiments performed on the distal femoral epiphysis of baby rabbits. In the second report by Key and Ford it was shown that small Vitallium nails driven through the epiphysis and across the epiphyseal plate from the intercondylar notch of the femur in a small group of five rabbits did not cause deformity or interference with growth. Of these five rabbits, two showed one millimeter of overgrowth of the nailed femur as compared with the control side; two rabbits showed one millimeter less growth; and in one rabbit the experimental and control femora were equal in length. It was apparent that no significant alteration of growth of the femora was produced by this procedure.

Since Vitallium nails were used in that experiment we wondered if stimulation of growth might be obtained if similar experiments were performed using irritating metals.

Clinically, stimulation of linear growth in long bones of children or adolescents may be seen as the result of fracture, osteomyelitis, alteration in circulation, joint infection, tumor, or congenital anomaly. Experimentally and clinically, bone growth has been stimulated by placing foreign materials in the metaphyseal area near the epiphyseal cartilage. Unfortunately, this method is not dependable, accurate, or consistent. As bone grows, the epiphyseal cartilage moves away from its stimulating influence. For that reason we believed that placing nails across the epiphysis would allow any stimulating influence to remain in continuous contact with the epiphyseal cartilage.

Bohlman, in 1929, reported attempts to stimulate longitudinal growth in guinea pigs. Among other substances placed in drill holes in the tibia, he used iron, iron oxide, copper, copper oxide, lead, and lead carbonate. No stimulation, only slight shortening, resulted. Wu and Miltner found no stimulation of growth when lead shot was placed in drill holes in the tibia in rabbits. Chapchal and Zeldenrust inserted steel, copper, iron, and zinc near the epiphyseal cartilage in rabbits and obtained alteration in growth of from 3.5 millimeters of shortening to 8.3 millimeters of overgrowth. They worked with both the femur and the tibia. Herndon and Spencer placed a copper plug in a drill hole in the distal metaphysis of the femur in ten rabbits. No appreciable linear acceleration of growth resulted. In a large series of dogs, Wilson[10,11] obtained a slight increase in leg length in young puppies by inserting in the bone combinations of copper, iron, aluminum, steel, brass, zinc, nickel, silver, and constantan. The most stimulation was obtained with copper and constantan, using a plate made of the two metals, fastened to the bone with screws. He also reported some similar work in children in which a maximum of one-half inch of stimulation in leg length was obtained in one case. Pease, in 1952, gave a preliminary report of seven children in whom he had inserted paired screws of mismatched metals to stimulate growth in shortened lower limbs. He obtained from 0.2 to 3.0 centimeters of stimulation. Clinical

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reports by Accinno and Parker described eight children in whom stimulation of bone growth was attempted by the placing of two stainless-steel screws in the metaphysis; an average stimulation of 0.11 inch resulted. Another seven children had the same procedure done on the short limb in association with stapling of the normal limb, resulting in a correction of from one-fourth to one inch of the limb-length discrepancy.

According to Haas, the placing of metal pins straight across the epiphysis of the radius in a dog caused definite restriction of growth unless the pins were removed immediately. Leaving the pin across the epiphysis for as much as twenty-one days caused some restriction of growth.

METHOD

In the present series of experiments, four groups consisting of five to seven baby rabbits were operated on, and small commercial nails of various metals were driven through the epiphysis and epiphyseal cartilage into the distal metaphysis of the right femur. In the fifth group two nails of different metals were

FIG. 1

A copper nail was inserted through the epiphysis and across the epiphyseal plate in the right femur. Four millimeters of shortening resulted. In the lateral view an osteophyte is noted on the front of the operated right femur. The tibiae were of equal length.

driven across the epiphysis but they were placed near the medial and lateral edges. The purpose in doing this was to keep the metals in contact with the epiphysis during growth so that any stimulating effect of the metals on the epiphyseal cartilage would be continuous.

All experiments were carried out on rabbits three to four weeks old weighing from 400 to 600 grams. Preliminary basal anesthesia of intravenous nembutal was administered and supplemented by drop ether, a small mask being used. The right hind leg was treated with a commercial depilatory and then prepared with tincture of merthiolate on the skin; sterile drapes were used. A curved incision

was made over the lateral aspect of the knee down through the deep fascia. A medial incision was then made through the capsule of the knee joint, and the patella was dislocated laterally. With a scalpel a small round portion of articular cartilage was excised from the intercondylar notch, and a hole one-eighth of an inch in diameter was drilled through the exposed subchondral bone in the notch. A small nail was then driven through the center of the epiphysis and across the epiphyseal plate into the metaphysis, with the head of the nail recessed into the hole previously drilled in the epiphysis. The wounds were closed with interrupted silk sutures. This procedure was carried out in the first four groups of animals in which nails of copper, steel, brass, and nickel-plated steel were used.

In the fifth group of animals the distal part of the femur was exposed in the same manner, and a small drill hole was made near the medial and lateral margins of the articular cartilage. A small steel nail was driven vertically up the medial femoral condyle, and a brass nail was driven vertically up the lateral femoral condyle.

FIG. 2

A steel nail was inserted in the right femur through the epiphysis and across the epiphyseal plate, and, at sacrifice, three millimeters of shortening were present as compared with the control. Expansion of the mid-shaft of the femur is noted in the anteroposterior and lateral views. This was the only animal that demonstrated such expansion. The tibia was not shortened.

Anesthesia in these small animals was a difficult problem, and during the experiments fourteen animals died therefrom.

The animals were sacrificed three to six months after surgery.

At the time of sacrifice the femur and tibia from both lower extremities were dissected from each animal without cutting of the ligaments of the knee joint. After fixation in formalin these bones were examined grossly. Histological sections were prepared from some of the bones by decalcification in nitric acid and staining with hematoxylin and eosin. Anteroposterior and lateral roentgenograms of all the bones were obtained, with the right and left femur and tibia from each

animal resting side by side on cardboard film holders and the x-ray tube forty inches from the film.

With this technique the lengths of the bones, as measured from the roentgenograms, were about one millimeter more than the actual lengths determined by direct measurement. Since essentially the same magnification was present for all bones, the differences in the lengths of the control and experimental femora were determined from the roentgenograms, and these measurements were assumed to be accurate to within one millimeter.

RESULTS

In the animals in Group I a copper nail three-quarters of an inch in length was driven through the distal femoral epiphysis and across the epiphyseal plate. There were five surviving animals, and these were sacrificed six months after operation (Table I). No infections were present. In each instance the defect from the nail hole in the hyaline articular cartilage had healed smoothly with fibrocartilaginous tissue. Minor degenerative arthritic changes were present in the knee joint on the operated side. Except for this and the presence of the nail, the roentgenographic appearance of the control and experimental femora was the same (Fig. 1). One femur showed no change in length compared with its control,

FIG. 3

A brass nail was inserted through the epiphysis and across the epiphyseal plate into the metaphysis of this right femur. At the time of sacrifice the femur on the side of operation was two millimeters longer than the control. The tibiae were of equal length.

but the remaining four were from one to four millimeters shorter—an average of 1.6 millimeters of shortening. No inequality in length of the tibiae was found in any of these animals.

In the seven animals in Group II a small steel nail five-eighths of an inch in length was placed through the epiphysis, and the animals were sacrificed six months after surgery. Except for minor arthritic changes in several knees, the

presence of the retained silk sutures, and the defect in the articular cartilage in the intercondylar notch, the experimental femora were similar to the control ones. The roentgenogram of one of the nailed femora (Fig. 2) showed broadening of the diaphysis beginning in the middle third of the shaft and extending down to the epiphysis. This broadening began at about the level at which the original surgical trauma to the bone had occurred. This femur also showed a slight increase in anterior bowing. By measurement, two of the nailed femora were one millimeter longer, two were two and three millimeters shorter than their controls, and three were the same length as their controls. This gave an average shortening of 0.04 millimeter (Table I). In four rabbits the tibiae were of equal length on each side. In two rabbits there was one millimeter of shortening of the tibia on the experimental side, and in another the tibia on the experimental side had been fractured and was six millimeters shorter than the opposite tibia.

In the animals in Group III a small brass nail one-half of an inch in length was inserted through the distal epiphysis in the same manner as previously described (Fig. 3). Five animals survived and were sacrificed five months after

FIG. 4

A nickel-plated nail was placed through the epiphysis and across the epiphyseal plate of the right femur in this animal. A fairly large osteophyte is noted on the front of the operated femur in the lateral and anteroposterior views. This femur was three millimeters shorter than its control. The tibiae were of the same length.

surgery. The knee joints on the side of operation again showed minimum changes of traumatic arthritis and healed defects at the site of insertion of the nail. Except for the presence of the nail in the roentgenogram, there was no difference between the nailed and the control femur (Fig. 3). By measurement, two femora were equal in length to their controls, one was two millimeters longer, and two were one millimeter shorter (Table I). There was no difference in the length of three tibiae, one tibia was one millimeter longer, and one was one millimeter shorter.

In the animals in Group IV, a steel nail plated with nickel, three-quarters of an inch in length, was used in the same manner. There were seven surviving animals, which were sacrificed five months after surgery.

In one of these animals osteomyelitis developed in the femur, and this bone was discarded. It was two millimeters shorter than the femur on the opposite side, whereas the corresponding tibia was three millimeters longer than the opposite tibia, presumably because of growth stimulation caused by the adjacent infection in the femur. In the remaining six animals, slight to moderate degenerative arthritic changes in the knee joints were noted on the side of operation. In one there was a moderately large osteophyte on the front of the distal part of the femur which was visible grossly and on the roentgenogram (Fig. 4). Roentgenograms of the nailed femora were otherwise similar to those of the controls. All the non-infected femora in this group were shorter than their controls by from one to three millimeters (Table I). In three animals the tibiae on the control and experimental sides were the same length. In two animals the tibia on the experimental side was one millimeter shorter, whereas in the remaining rabbit the tibia on the experimental side was one millimeter longer than the control.

FIG. 5

In this animal a steel nail was placed through the lateral side of the epiphysis and across the epiphyseal plate, and a brass nail was placed across the medial side of the right femur. At autopsy the femora were of equal length, and the right tibia was one millimeter longer than the left. Very slight lateral bowing is noted in the anteroposterior view.

In the animals in Group V a steel nail and a brass nail were driven through the distal femoral epiphysis and across the epiphyseal plate (Fig. 5). As might be anticipated, the more extensive trauma caused by the driving of the two nails across the epiphyseal plate resulted in more traumatic arthritic changes in the knee on the experimental side at the time of sacrifice three months after surgery.

Among the ten surviving animals the experimental femur was equal to the control femur in one, overgrown by one millimeter in two, and from one to six millimeters shorter in the remaining seven animals (Table I). The tibiae were

TABLE I

GROWTH DISCREPANCY

Experiment	Animal	Amount and Type of Growth Discrepancy		Control Femora (*Centimeters*)
		Femur (*Centimeters*)	Tibia (*Centimeters*)	
Group I: Copper nail; duration, six months	A 1	0.1; shortening	No discrepancy	
	A 2	0.1; shortening	No discrepancy	
	A 3	0.2; shortening	No discrepancy	
	A 4	No discrepancy	No discrepancy	
	A 5	0.1; shortening	No discrepancy	
	Average:	0.16 (1.68%); shortening		9.88
Group II: Steel nail; duration, six months	B 1	No discrepancy	No discrepancy	
	B 2	0.3; shortening	No discrepancy	
	B 3	0.2; shortening	0.6; shortening	
	B 4	0.1; overgrowth	0.1; shortening	
	B 5	No discrepancy	No discrepancy	
	B 6	0.1; overgrowth	No discrepancy	
	B 7	No discrepancy	0.1; shortening	
	Average:	0.04 (0.4%); shortening	0.02; shortening	9.86
Group III: Brass nail; duration, five months	E 1	No discrepancy	0.1; shortening	
	E 2	0.1; shortening	0.1; shortening	
	E 3	No discrepancy	No discrepancy	
	E 4	0.2; overgrowth	No discrepancy	
	E 5	0.1; shortening	No discrepancy	
	Average:	equal to control femora		9.42
Group IV: Nickel-plated steel nail; duration, five months	O 1	0.1; shortening	0.1; shortening	
	O 2	0.1; shortening	0.1; shortening	
	O 3	0.1; shortening	0.1; overgrowth	
	O 4	0.2; shortening	No discrepancy	
	O 5	0.1; shortening	No discrepancy	
	Average:	0.15 (1.6%); shortening		10.02
Group V: Steel and brass nails; duration, three months	T 1	0.1; shortening	No discrepancy	
	T 2	0.3; shortening	0.1; overgrowth	
	T 3	0.2; shortening	No discrepancy	
	T 4	0.1; shortening	0.1; overgrowth	
	T 5	0.4; shortening	No discrepancy	
	T 6	No discrepancy	0.1; overgrowth	
	T 7	0.6; shortening	0.1; overgrowth	
	T 8	0.4; shortening	0.1; shortening	
	T 9	0.1; overgrowth	No discrepancy	
	T 10	0.1; overgrowth	No discrepancy	
	Average:	0.19 (2.98%); shortening		9.06

equal in length in five cases, whereas in the other five there was a discrepancy of one millimeter. In several femora, especially in the anteroposterior view, there was slight broadening of the distal half of the femur. In five animals the two nails did not remain in position in the epiphyseal portion of the femur; one or both nails remained in the diaphysis as the distal portion of the femur continued to grow. In one animal a varus deformity developed with six millimeters of shortening. This was the only animal in the five groups of experiments in which a marked angulatory deformity developed. In this instance it appeared that the head of the nail on the medial side of the femur had been driven across the epiphyseal plate at the time of insertion, whereas on the lateral side only the shaft of the nail had penetrated the plate. The resultant extensive damage to the plate on the medial side had apparently arrested growth here, causing marked shortening and a varus deformity.

MICROSCOPIC FINDINGS

Histological sections were prepared from the distal ends of both the experimental and the control femora of several animals in each group. No foreign-body reaction, no cellular infiltration, and no granulation tissue were seen. In some specimens the tract of the nail was lined by a thin fibrous tissue, and the surface that was in contact with the nail tract was flattened. Except for the defect caused by the nail, the bone structure in these sections appeared normal. The defect in the articular cartilage of the femur and in the epiphysis that had been drilled out in order to recess the head of the nail was filled in with bone which was covered by fibrocartilage. Longitudinal sections through the nail tract showed some deformation of the epiphyseal cartilage in the region of the nail tract where the nail had caused local retardation of growth. As may be seen in Table I, this did not cause cessation of growth of the femur in any animal. The histological picture was not influenced by the number of nails used; it was the same after the insertion of either one or two nails.

CONCLUSION

The placing of small nails of several different metals through the lower femoral epiphysis and across the epiphyseal cartilage of rabbits, both in the center and at the periphery of the plate, resulted in minor variations in length of the growing bone. In this small series of experiments slight retardation occurred more often than did slight stimulation, and in some animals neither occurred. The placing of two different metals through the lower femoral epiphysis and across the epiphyseal plate resulted in slight stimulation of growth of the femur in only two of ten rabbits.

From these experiments it would appear that the placing of a metallic nail through the epiphysis of a long bone neither appreciably retards nor stimulates growth of the femur in the rabbit.

REFERENCES

1. Accinno, M.A., and Parker, M. V.: Leg Length Inequality Treated by Epiphyseal Arrest and Stimulation. A Preliminary Report. J. Med. Assn. Alabama, **24**: 38–41, 1954.
2. Bohlman, H. B.: Experiments with Foreign Materials in the Region of the Epiphyseal Cartilage Plate of Growing Bones to Increase Their Longitudinal Growth. J. Bone and Joint Surg., **11**: 365–384, Apr. 1929.
3. Chapchal, G., and Zeldenrust, J.: Experimental Research for Promoting Longitudinal Growth of the Lower Extremities by Irritation of the Growth Region of Femur and Tibia. Acta Orthop. Scandinavica, **17**: 371–396, 1948.
4. Ford, L. T., and Key, J. A.: A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits. J. Bone and Joint Surg., **38-A**: 84–92, Jan. 1956.
5. Haas, S. L.: Restriction of Bone Growth by Pins through the Epiphyseal Cartilaginous Plate. J. Bone and Joint Surg., **32-A**: 338–343, Apr. 1950.
6. Herndon, C. H., and Spencer, G. E.: An Experimental Attempt to Stimulate Linear Growth of Long Bones in Rabbits. J. Bone and Joint Surg., **35-A**: 758–762, July 1953.
7. Key, J. A., and Ford, L. T.: A Study of Experimental Trauma to the Distal Femoral Epiphysis in Rabbits—II. J. Bone and Joint Surg., **40-A**: 887–896, July 1958.
8. Pease, C. N.: Local Stimulation of Growth of Long Bones. A Preliminary Report. J. Bone and Joint Surg., **34-A**: 1–24, Jan. 1952.
9. Siffert, R. S.: The Effect of Staples and Longitudinal Wires on Epiphyseal Growth. An Experimental Study. J. Bone and Joint Surg., **38-A**: 1077–1088, Oct. 1956.
10. Wilson, C. L.: Experimental Increase in Leg Length. A Preliminary Report. Surg. Forum (1951), 438–443, 1952.
11. Wilson, C. L., and Percy, E. C.: Experimental Studies on Epiphyseal Stimulation. J. Bone and Joint Surg., **38-A**: 1096–1104, Oct. 1956.
12. Wu, Y. K., and Miltner, L. J.: A Procedure for Stimulation of Longitudinal Growth of Bone. An Experimental Study. J. Bone and Joint Surg., **19**: 909–921, Oct. 1937.

A New Bone Affection: Feathering*

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This paper presents the microscopic characteristics and age incidence of a peculiarity of skeletal mineralization previously unrecognized. This phenomenon, which I term *feathering*, is characterized by the existence of incompletely mineralized organic matrix which, in some instances, has been observed in more than half of the skeletal volume. At present there are no known signs, symptoms, or blood-chemistry findings which are characteristic in patients whose bones show the feathered state, although the microscopic features are characteristic.

Feathered bone is of interest as a biological phenomenon in man. Its presence may be an unknown variable responsible for some of the variability in results that has plagued investigations of osteoporosis, osteomalacia, the physical characteristics of bone, the water content of bone and matrix in health and disease, and the rate of exchange of electrolytes, buffer materials, and radioisotopes between bone and blood.

To understand feathered bone the reader must possess a clear understanding of the nature of osteoporotic bone and of osteomalacic bone.

In osteoporotic bone the bone substance is of normal quality with respect to the proportions of organic and inorganic material, the strength, the hardness, and the rigidity. The quantity of bone, however, is diminished because of thinning of the cortices and trabeculae, the presence of fewer trabeculae, and the enlargement of Haversian canals and marrow spaces. The total mass and volume of bone substance (marrow excluded) are thus reduced, rendering the bone less dense on the roentgenogram. Doubtless, some of the past confusion concerning osteoporotic bone arose from the erroneous assumption that density on the roentgenogram and density of the bone substance (the physicist's density) are synonymous [1,3,4,17].

In osteomalacic bone the bone substance is abnormal. Abnormally large numbers of osteoid seams line the Haversian canals and marrow spaces. When osteoid comprises an appreciable fraction of the total bone volume, the bone contains less mineral and more water per unit volume of matrix and becomes grossly softer, less rigid, and less strong. The total amount of bone substance in an osteomalacic skeleton may or may not be decreased. If it is decreased, the bone is then osteoporotic as well as osteomalacic. Such a decrease in the amount of bone is not an essential part of the osteomalacic state [1,3,7,15,17].

In the course of examining fresh, undecalcified bone sections from a large number of patients, osteoporotic bone, osteomalacic bone, and the condition to be described — feathering — were seen. These three conditions may exist singly or in any combination and degree. It is this coexistence which has probably prevented prior recognition of feathering as a separate, distinct process in bone.

MATERIALS AND METHODS

Sections from ninety-five bones obtained from eighty-nine patients were suitable for study. Children, patients with known metabolic bone disease, and patients with local bone lesions (such as fracture, Paget's disease, or skeletal metastases) were excluded from the study. There were fifty-one male and thirty-eight female patients whose ages ranged from fourteen to ninety years. Specimens were obtained at autopsy in fifty-seven instances and at operation in thirty-two.

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In all, there were thirty-five clavicles, twenty-two ribs, twenty-one tibiae, six ilia, four femora, three fibulae, three metatarsals, and one radial head.

Fresh, undecalcified, ground sections of bone twenty to forty micra thick were prepared and stained with basic fuchsin by previously described techniques [8,10]. Staining variations in different areas of the cortical bone were then investigated.

Under physiological conditions of temperature, pressure, and pH the permeability of fresh bone *in vitro* to most organic and inorganic molecules varies with the degree of mineralization. A comparative study of ground sections, using quantitative microradiography, indicates that permeability to fuchsin ceases when mineralization is in excess of about 80 per cent of maximum [9]. For the purpose of this study complete mineralization has been assumed to exist when the

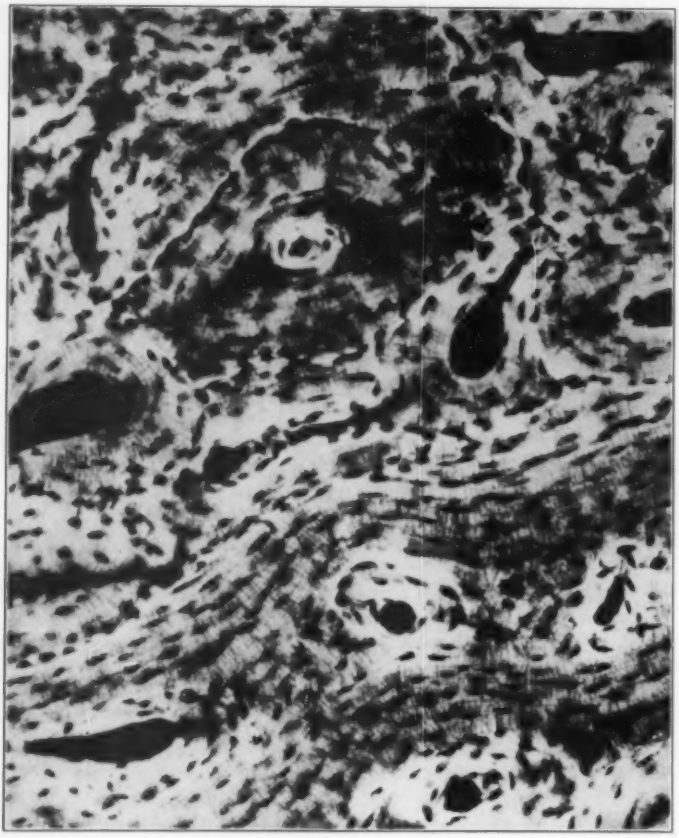

FIG. 1

Cross section of a femur of a woman, thirty-eight years old. The femur was amputated because of a minute fibrosarcoma in the quadriceps.

The stain does not permeate the bone substance but is present as a layer on the walls of the bone spaces. The apparent diffusion at opposite quadrants of the osteon near the center is due to overlapping of large numbers of canaliculae present throughout the depth of the section (undecalcified section, basic fuchsin, × 150).

matrix fails to stain with 1 per cent basic fuchsin in 40 per cent ethanol. This assumption is made with full realization that there is no agreement as to what truly represents complete mineralization, and with the knowledge that a continuous spectrum of mineral densities occurs in the living, adult skeleton. The

presence or absence of fuchsin permeability merely divides this spectrum into two parts.

In a section of completely mineralized bone stained with basic fuchsin, only the walls of the spaces in the bone, that is the lacunae, canaliculae, Haversian and Volkmann canals, and the protoplasmic contents of these spaces are stained. The bone surrounding these spaces, exclusive of their walls, is unstained and colorless, a point which has been missed by other workers because surface stain was not removed by further grinding after completion of the staining procedure (Fig. 1).

Incompletely mineralized bone, on the other hand, is diffusely stained by basic fuchsin, the density of staining increasing as the degree of demineralization increases. Other histological dyes and staining techniques, utilizing metallic sulphides, alizarin, permanganate, and dichromate yield similar results.

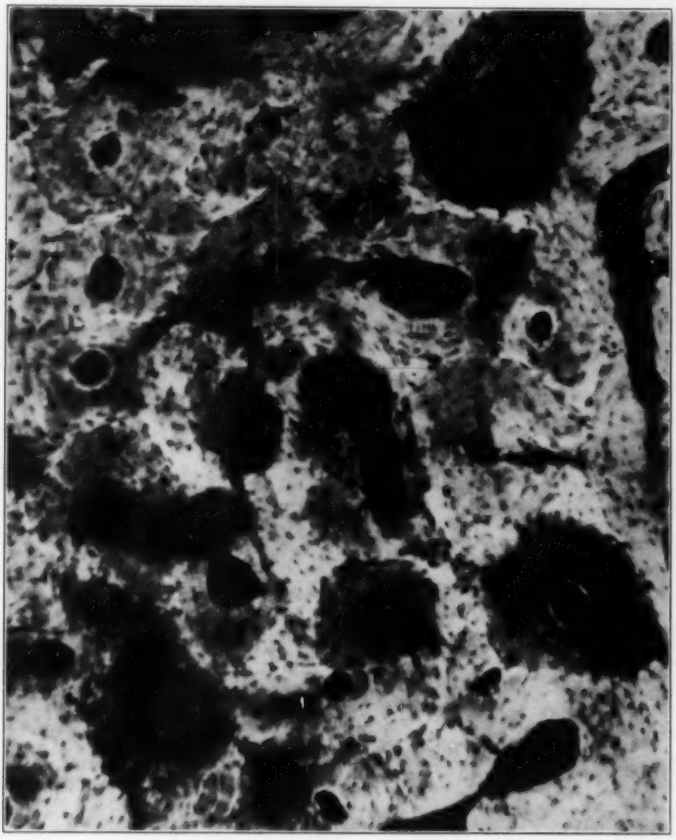

FIG. 2

Cross section of a clavicle of a man, twenty-six years old. The patient died of carcinomatosis without bone metastasis. Several osteons wholly or partly feathered are visible; the diffuse staining causes them to appear black. The thin, normally mineralized ring separating the Haversian canals from the feathered bone is evident.

When a ground section of bone is allowed to dry at room or body temperature, air enters the matrix in amounts varying according to the degree of mineralization, as indicated by the appearance of the dried ground section under the microscope. The normally mineralized portions of the matrix remain transparent

because air does not penetrate. By contrast, the incompletely mineralized portion of the matrix becomes more or less dark and opaque according to the amount of air penetrating the matrix during drying. This is another manifestation of the variation in permeability of the matrix, which is related to the amount of mineralization.

Feathered bone is incompletely mineralized, for it stains diffusely with fuchsin and with the other reagents mentioned and aerates on drying in air. In the early phases of this work fuchsin-stained sections were compared with water mounts by phase and interferometric methods and with aerated mounts by brightfield technique. After about the first twenty cases the consistency with which the various methods duplicated each other led to the use of fuchsin-stained sections alone, since these sections are permanent.

Measurement

A method was desired for the measurement of the feathering process in bone which would quantitate two variables: (1) the optical density of the fuchsin stain, and (2) the percentage of the section area that is feathered.

Determination of stain density proved to be a complicated procedure and was not attempted in the present study. Instead, an area-estimating method was used. This consisted in selecting six reference slides according to clearly discernible differences in the amount of section area affected. The six slides spanned the range from zero to maximum involvement. All sections from the cases in Table I were then compared at low magnification (× 30) with the reference slides and tabulated in the appropriate group. The reference slides were finally measured with a Leitz integrating eyepiece micrometer to determine the percentage of the area of the bone section that was feathered. Although the probable instrumental error during the measurement just described was about 1 per cent, the results have been rounded off to the figures given in the next paragraph in view of the much larger errors associated with a visual comparison method.

As finally tabulated, the specimens were graded according to the percentage of the area of the bone section involved with feathering: Grade 0, 0 per cent; Grade 1, from 0 to less than 2 per cent; Grade 2, from 2 per cent to less than 7 per cent; Grade 3, from 7 per cent to less than 17 per cent; Grade 4, from 17 per cent to less than 37 per cent; and Grade 5, over 37 per cent.

Since the degree of feathering differed considerably among the different quadrants of a cross section, but differed little at varying levels along the longitudinal axis of the diaphysis, only measurements of complete cross sections were accurate. Ten tibiae are included in the case material even though only the anterior half of the diaphysis was available. Although the level from which the sections were taken is not specifically recorded, in most cases it is the middle third of the bone. This is justified by the fact that in six patients sections from multiple levels of the diaphysis in fifteen bones were examined and found to exhibit little variation in the degree of feathering in varying levels.

The degree of involvement of different bones of the same skeleton was evaluated in eighteen bones from these same six patients. A variation of less than one grade was found. In only one case was it possible to compare the axial and appendicular skeleton (Case G.I.), so it is not possible to infer from the present material whether these two skeletal partitions bear a consistent relationship to each other in their degree of feathering.

RESULTS

Microscopy

In fuchsin-stained, ground, cross sections of bone, feathered bone was immediately evident as dark red areas. Often, clear unstained areas of bone, several micra thick, were observed surrounding the Haversian canals and along the cement lines. Considerable granularity was seen in most of the feathered

bone. (Haversian systems containing osteoid seams were not considered to be feathered for reasons which will be discussed later.)

When a minor degree of feathering was present, only Haversian systems were affected. One, two, or all quadrants of a single Haversian system might be involved. When feathering affected from 15 to 20 per cent of the area of the section some of the extra-Haversian bone (interstitial lamellae) also exhibited involvement, but even here the cement lines remained clear. With the severest degree of feathering as much extra-Haversian as Haversian bone was affected (Figs. 2 and 3).

In longitudinal sections, feathering was observed for several millimeters along the course of the affected Haversian systems and extra-Haversian bone. In some systems there were gradual variations in stain density and in amount of feathering along the longitudinal axis of the affected Haversian systems. The considerable length of involvement as compared to the thickness of the measured sections obviated any significant measuring error due to overlap or to varying section thickness.

FIG. 3

Same section as Fig. 2, but higher-power magnification (× 300), revealing details of feathered osteons.

With an objective of high numerical aperture, feathered bone appeared much more granular than the neighboring, completely mineralized bone. Granularity was more evident in the water and aerated mounts than in the resin mounts. In the granular portions fine fibrillae 0.1 micron in diameter and 3.0 micra in length could be seen spiraling along the presumed course of the collagen bundles. Phase and interference microscopy of thin water mounts revealed that feathered bone had a shorter optical path-length than completely mineralized bone.

If a wet mount was decalcified by flowing dilute acid under the coverslip all evidence of feathering disappeared. There were no remaining granularity, fibrillae, or difference in optical path-length.

TABLE I

No. of Grade and Grade of Feathering (*Per Cent*)	No. of Case	Bone	Age (*Years*)	Sex
	899715	Tibia	63	M
0 (0)	932013 c	Rib	70	F
	741771 b	Tibia	38	F
	69528	Tibia	50	M
1 (from more than 0 to less than 2)	846132	Clavicle	45	F
	865206	Clavicle	51	F
	11955	Tibia	73	M
	889538	Metatarsal	49	M
	12050	Tibia	68	F
	12064	Tibia	64	M
	906377 b	Femur	16	M
	426260 a	Clavicle	59	M
	135260	Clavicle	58	M
	929137 a	Rib	29	F
	12084	Tibia	51	M
	899314 a	Clavicle	28	M
	449890	Rib	45	F
	11845	Tibia	58	M
	463745	Clavicle	62	F
	922578	Femur	67	F
	922578	Tibia	67	F
	922578	Fibula	67	F
	922578	Metatarsal	67	F
	11828	Tibia	74	M
	920886 a	Tibia	63	M
	920886 a	Fibula	63	M
	920886 a	Metatarsal	63	M
	11806	Tibia	68	F
	918255 b	Radial head	58	M
	645786 a	Rib	44	F
	11818	Tibia	72	M
	575149	Clavicle	38	M
	559821	Clavicle	52	F
	505537 c	Rib	49	F
	498116	Rib	47	F
	G.I.	Tibia	63	M
	12177	Tibia	67	F
	12177	Fibula	67	F
	H.J.	Tibia	26	M
2 (from 2 to less than 7)	890793	Clavicle	62	M
	892435	Clavicle	67	M
	132447	Clavicle	54	M
	897317	Clavicle	58	M
	242623	Clavicle	51	F
	933423 b	Rib	26	M
	928734 a	Rib	44	F
	928459 a	Rib	51	F
	927602	Rib	59	M
	924957 a, b	Rib	21	M
	843452 b	Femur	16	F
	198963	Clavicle	64	M
	010736	Clavicle	76	F
	701617	Rib	30	F
	135820 a, b, c	Rib	61	M
	662925	Clavicle	65	M
	924416	Rib	18	M
	11885	Tibia	90	F
	920431	Clavicle	63	F
	11846	Tibia	14	F

TABLE I—*(Continued)*

No. of Grade and Grade of Feathering *(Per Cent)*	No. of Case	Bone	Age *(Years)*	Sex
	550879	Clavicle	53	M
	483350	Clavicle	64	M
	459576	Rib	48	M
	27075 c	Rib	65	F
	A.B.	Ilium	67	M
3 (from 7 to less than 17)	899314 a	Clavicle	29	M
	928734 a	Rib	44	F
	927602 a	Rib	59	M
	926196 a, c	Rib	57	M
	807580	Clavicle	56	F
	920789 b	Clavicle	59	M
	919913	Clavicle	65	M
	919123	Clavicle	38	F
	919079	Clavicle	62	M
	583346	Clavicle	62	M
	182502	Ilium	65	M
	12178	Tibia	64	F
	12396	Tibia	63	M
	G.H.	Ilium	65	M
	M.P.	Tibia	46	F
4 (from 17 to less than 37)	853071	Clavicle	41	F
	855929	Clavicle	15	F
	871829	Clavicle	25	M
	897487	Clavicle	55	F
	927890 a, b	Rib	23	F
	831088	Rib	28	M
	924525	Clavicle	71	M
	027176	Clavicle	76	F
	A.Q. a	Femur	66	F
5 (over 37)	895595	Ilium	52	M
	761685	Clavicle	29	M
	722345 b	Rib	58	F
	922299 a	Clavicle	64	M
	918888	Clavicle	83	M
	435303	Ilium	65	F
	G.I.	Ilium	63	M

Counts were made of the osteoid seams in the sections studied in this series of cases. The normal incidence of seams in adult rib without much feathering was equivalent to from 0.5 per cent to 1.5 per cent of the number of longitudinal vascular channels present in the section. Similarly, seam counts in ribs with 25 per cent or more feathering were from 0.1 to 2.0 per cent. Hence, the seam counts did not vary significantly with the amount of feathering [13].

Counts of empty lacunae were done to compare the incidence of empty lacunae in feathered bone with the incidence of empty lacunae in new Haversian systems containing an osteoid seam. In the systems with an osteoid seam the average percentage of empty lacunae was about 1, varying from 0 to 2. In feathered systems the average incidence was about 10 per cent, the range being from 1 to 80 per cent. In no case did feathered systems show a lower incidence of empty lacunae than new systems with seams present in the same section. It is worth noting that usually, but not always, there were more empty lacunae in fully mineralized Haversian systems and in the extra-Haversian bone than in feathered bone in the same section [11].

TABLE II

PERCENTAGE OF AREA OF FEATHERING IN AFFECTED BONE

No. of Grade	Grade of Feathering (*Per Cent*)	Percentage
0	0	4.2
1	From more than 0 to less than 2	36.8
2	From 2 to less than 7	26.3
3	From 7 to less than 17	15.8
4	From 17 to less than 37	9.5
5	Over 37	7.4

Incidence

Study of Tables I and II will reveal the following:

The arithmetic mean age for all cases is 52.3 years.

The degree of feathering is not correlated with age. The average involvement in the sixteen patients less than thirty-six years old and in the thirty-eight patients over sixty is the same: 5 per cent.

The average involvement of the twenty-one tibiae is 1.2 per cent, whereas that of the twenty-two ribs is 3.0 per cent, suggesting that the axial skeleton is more affected than the appendicular. This is a matter for further study.

In Table I the small letter *a* after the case number indicates that there was sufficient cancellous bone in the sections to permit comparison to be made between the degree of feathering in cortical and cancellous bone. Minor variations were observed.

The small letter *b* indicates cases in which specimens became available because of sudden trauma, fatal hemorrhage, acute fatal illness, or amputation for reasons other than vascular disease. Such cases are considered controls and exhibit the entire range in severity of feathering.

The small letter *c* designates cases in which the cortex was less than 0.5 millimeter in thickness. These four patients had osteoporotic bone but did not have the usual clinical symptoms of osteoporosis during life. These cases do not exhibit a group reference.

No significant difference in grading exists between male and female, Negro and white, or young and old patients. No correlation with medication or illness has as yet been apparent.

DISCUSSION

It would appear that feathered bone has been seen before but not recognized as an entity. Microradiograms published by other workers have revealed "low density osteons" which contain less mineral than the majority of osteons visualized. These low-density osteons have been considered to be newly formed, and it has been assumed that they either contain an osteoid seam or recently contained one. The low mineral density has been assumed to be the result of the comparative youth of the affected osteons [5,6,7]. Since special, laborious techniques are needed to demonstrate osteoid in microradiograms and to obtain microradiograms of complete cross sections of bones, it is natural that these assumptions should have gone unchallenged. Many of the low-density osteons seen in the microradiograms of non-osteomalacic, adult bone have the stigmata of feathered osteons, namely, a densely mineralized ring lining the Haversian canal, inhomogeneous distribution of mineral among the quadrants of the osteon, and cement lines which are often radiodense. In view of this it seems reasonable to assume that these low-density osteons are indeed feathered.

The possibility that feathered bone, whether visualized by my techniques

or by microradiography, is comparatively young bone, must be considered. In fact, feathering can be considered a specific affection of bone only if it can be proved that feathered bone is not comparatively youthful and is not a normal transition stage between new, fuchsin-permeable bone and mature, fuchsin-impermeable bone. With this in mind the following evidence is presented:

1. The pattern of stain density in new bone with an osteoid seam and in feathered bone is different. In new bone, staining is most intense at the wall of the Haversian canal and least intense at the cement line, in contrast to feathered bone which is stained diffusely, as has been described and is illustrated in the accompanying photomicrographs. This difference appears to be related to something other than the age of the bone involved.

2. If feathered bone were merely youthful bone then large amounts of feathering in adult bone could only be explained by an increased rate of remodeling so that in a given unit of time more new osteons are being formed than is normal in a statistical sense. If this were the case increased numbers of osteoid seams would be present. Seam counts revealed that there is no increase in the numbers of seams in the sections with large amounts of feathering. In fact, in some cases the seam incidence in the feathered bone was considerably less than normal.

3. There are consistently more empty lacunae in feathered than in new bone in the same section. Occasionally, feathered bone has been observed to contain more empty lacunae than the surrounding normal Haversian and extra-Haversian bone. Since the number of empty lacunae is known to increase gradually with age [11], this is suggestive but not conclusive evidence that feathering is not related to the age of the bone.

4. Conclusive evidence that feathered bone, at least on occasion, is old bone has only recently come to hand.

It has been observed that the tetracycline antibiotics become fixed in new, progressively mineralizing bone *in vivo*. Once so fixed in the bone the tetracycline remains *in situ* until remodeling processes destroy the bone labeled by the tetracycline [12, 16]. Bone which is already normally mineralized or partly mineralized when the tetracycline administration is begun does not become permanently stained by the drug. The tetracycline fixed in the bone may be seen in suitably prepared sections examined by appropriate microscopic methods even though the bone sections are obtained several years after the administration of the drug [12,14,16]. If the time of drug administration is known, then the Haversian systems in the bone sections labeled with tetracycline are identified as having been in the process of formation when the patient received the drug. In this manner the age of a Haversian system may be determined.

In my collection of human material there are over thirty instances where tetracycline antibiotics had been given prior to death or surgery. All of these bone sections reveal the presence of the drug. In one of these cases there is about 20 per cent of feathering of a rib and clavicle. This patient received tetracycline in 1956 and died in late 1959. In the bone sections obtained at autopsy one-fifth of the Haversian systems labeled with tetracycline in 1956 are feathered. These feathered osteons must therefore be three years old. Since it is known that new bone normally becomes completely mineralized in about three months or less, these three-year-old Haversian systems are not comparatively youthful.

The observations in this case suggest that feathered bone is either created *de novo* or it is the result of halisteresis — partial decalcification — of bone originally normally mineralized. At present the preponderance of evidence indicates that halisteresis does not occur.

Whatever its genesis, feathering appears to be a newly recognized state of bone. The possible influence of large amounts of feathering on the physiology of the skeleton is a subject for future work.

From what has been said so far it might appear that feathering is static — an

unchanging feature of bone. This is probably not the case since nothing else in human physiology is static. It seems more likely that feathered bone starts as normal, newly formed bone matrix but some agent or event delays its mineralization with the result that this matrix remains permeable to fuchsin for many years instead of just for a few months, as is normally the case. With time, mineralization may proceed to the point where the matrix becomes impermeable to fuchsin and feathering disappears. What governs the amount of feathering present at any one time is not known but it does not seem to be related necessarily to the rate at which the bone is being remodeled. The presence of a large amount of feathered bone probably represents an abnormal state. Much further work must be done to determine the genesis and evolution of feathered bone.

SUMMARY

An affection of bone, termed *feathering*, is described. Feathered bone is incompletely mineralized and has distinctive morphological features as seen in stained, fresh, undecalcified sections. It is different from osteomalacic and osteoporotic bone and may involve more than half of the skeleton. It has not yet been possible to correlate it with age, sex, disease, or medication.

REFERENCES

1. Aegarter, E. E., and Kirkpatrick, J. A.: Orthopaedic Diseases: Physiology, Pathology, Radiology. Philadelphia, W. B. Saunders Co., 1958.
2. Amprino, R., and Engström, A.: Studies on X-ray Absorption and Diffraction of Bone. Acta Anat., **15:** 1–22, 1952.
3. Anderson, W. A. D.: Pathology. Ed. 3. St. Louis, The C. V. Mosby Co., 1957.
4. Butler, R. W.: Osteoporosis of the Spine. J. Bone and Joint Surg., **35-B:** 691, Nov. 1953.
5. Carlström, D. G.: Some Aspects of the Ultrastructure of Bone. J. Bone and Joint Surg., **39-A:** 622–624, June 1957.
6. Engfeldt, Bengt: Recent Observations on Bone Structure. J. Bone and Joint Surg., **40-A:** 698–706, June 1958.
7. Engfeldt, Bengt; Zetterström, R.; and Winberg, J.: Primary Vitamin-D Resistant Rickets. III. Biophysical Studies of Skeletal Tissue. J. Bone and Joint Surg., **38-A:** 1323–1334, Dec. 1956.
8. Frost, H. M.: Preparation of Thin, Undecalcified Bone Sections by Rapid Manual Method. Stain Technol., **33:** 273–277, 1958.
9. Frost, H. M.: Some Observations on Bone Mineral in a Case of Vitamin D Resistant Rickets. Henry Ford Hosp. Med. Bull., **6:** 300–310, 1958.
10. Frost, H. M.: Staining of Fresh, Undecalcified, Thin Bone Sections. Stain Technol., **34:** 135–146, 1959.
11. Frost, H. M.: *In Vivo* Osteocyte Death. J. Bone and Joint Surg., **42-A:** 138–143, Jan. 1960.
12. Frost, H. M.: *In Vivo* Staining of Bone with Tetracycline Antibiotics. Stain Technol., in press.
13. Frost, H. M.: Measuring Osteoblastic Activity in Diaphyseal Bone. Stain Technol., in press.
14. Frost, H. M.: An Economical Microfluorescence Equipment. Henry Ford Hosp. Med. Bull., in press.
15. Levitt, M. F.; Turner, L. B.; Sweet, A. Y.; and Pandiri, Demetra: The Response of Bone, Connective Tissue, and Muscle to Acute Acidosis. J. Clin. Invest., **35:** 98–105, 1956.
16. Milch, R. A.; Rall, D. P.; and Tobie, J. E.: Fluorescence of Tetracycline Antibiotics in Bone. J. Bone and Joint Surg., **40-A:** 897–910, July 1958.
17. Snapper, I.: Bone Diseases in Medical Practice. New York, Grune and Stratton, Inc., 1957.

A Microchemical Study of the Developing Epiphyseal Plate

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The growth of long bones occurs at the epiphysis by the process of endochondral ossification. In this process, unorganized cartilage cells proliferate and become oriented to form columns of flattened cells separated by parallel bands of matrix. These cells become hypertrophic as they approach the zone of ossification, and the adjacent matrix becomes calcified to form the zone of provisional calcification [25]. The metachromatic staining characteristics of the cartilage matrix change during its transition from the non-calcified to the calcified state, and glycogen disappears abruptly from the hypertrophic cartilage cells as they mature. Alkaline phosphatase has been demonstrated to become increasingly active as calcium deposition occurs [1,7,8,24].

The process of endochondral calcification seems dependent on active carbohydrate metabolism. Gutman and associates observed that the enzyme inhibitors phlorhizin, iodoacetate, and fluoride block *in vitro* calcification of cartilage [9,11]. They and other workers have also demonstrated the presence in ossifying cartilage of several enzymes related to carbohydrate metabolism [2,8,24].

Quantitative microchemical techniques make possible investigation of the enzymatic and physical alterations that accompany endochondral-bone formation. Studies were undertaken to investigate the quantitative distribution of alkaline phosphatase and five enzymes participating in carbohydrate metabolism in four representative areas of the femoral epiphyseal plate in the dog. Furthermore, the techniques used were so adapted that they can be applied later to the study of biopsy material from diseased epiphyseal plates. The results are related to the total and the non-acid soluble solid and phosphorus content of these areas.

METHODS AND MATERIALS

The methods and equipment used were described previously [15,19] and only that information necessary for this report will be given here. A full discussion of the limitations, accuracy, and reproducibility of these methods has also been presented in previous publications [15-23].

Preparation of Tissues

The details of the procedure for obtaining suitable unfixed, histologically defined material have been described elsewhere [15]. Two newborn and two three-week-old puppies of unknown breed were sacrificed by cervical fracture. The rear extremities were removed by hind-quarter amputation, and the distal end of the femur scraped clean of the attached muscles and ligaments. The distal end of the femur was transected two millimeters proximal to the epiphyseal plate and split in the longitudinal plane with a razor blade. The blocks of tissue were then quickly laid on strips of filter paper for identification and ease of manipulation and immersed in liquid nitrogen. The time required for these procedures was less than four minutes. Sections twenty micra thick were cut on a microtome at −10 degrees centigrade. The sections were cut in an oblique manner across the epiphyseal plate so that the four areas demonstrated in Figure 1 were obtained [13,14]. At cutting temperatures significantly lower than −10 degrees centigrade the newly formed bone cut with difficulty and fragmented easily. The cut sections were

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placed in aluminum holders with one by 0.8 centimeter square openings and dried under high vacuum at −30 to −40 degrees centigrade. The material was stored *in vacuo* at −30 degrees centigrade until dissected [14,15].

Tissue Dissection

Before dissection of the tissue, the evacuated storage tubes containing the sections were warmed to room temperature, opened, and the dried sections removed and placed under a dissection microscope. At magnifications of from the tenth to the fortieth power individual, free and hypertrophic cartilage cells could be distinguished from the surrounding matrix in the unstained sections, and samples of tissue from the areas to be described could be obtained by free-hand

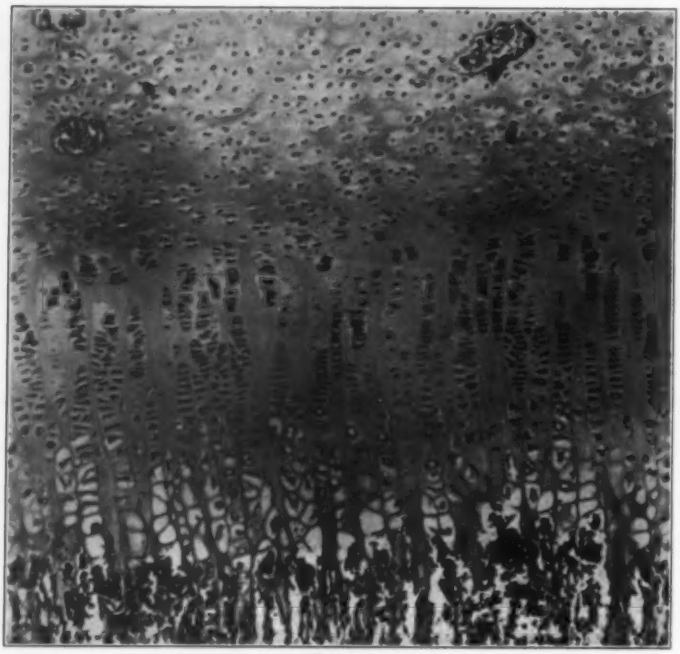
Unorganized cartilage cells
Proliferating cartilage cells
Hypertrophic cartilage cells
Zone of provisional calcification and primary spongiosa

FIG. 1

Cross section of the distal femoral epiphyseal plate of a newborn dog. The samples studied were removed from the locations indicated in the photomicrograph and are labeled accordingly (hematoxylin and eosin, × 70).

dissection with a No. 11 scalpel blade and hair point. In this manner tissue fragments weighing from 10^{-5} to 10^{-6} grams were obtained, care being taken to avoid blood capillaries. The sample weights were determined by optically measuring the displacement of a quartz fiber in a Lowry quartz fiber balance [15]. These weights are accurate and reproducible to within 3 per cent. The balance was calibrated fluorometrically, using quinine hydrobromide crystals [15]. Samples were selected from the four regions of the epiphyseal plate illustrated in Figure 1. For purposes of reference in this work these regions are identified as: unorganized cartilage cells, proliferating cartilage cells, hypertrophic cartilage cells, and primary spongiosa. The area designated as primary spongiosa also contains the zone of provisional calcification.

Analytical Methods

Total solid content: The volume of the dissected areas was determined by projecting the shadow of the sample through an optical system of known mag-

TABLE I

STANDARD CONDITIONS UTILIZED IN DETERMINING THE SIX ENZYMES STUDIED IN THE DOG EPIPHYSEAL PLATE

Enzyme	pH	Buffer	Substrate	Co-factors	Product measured F = fluorometric S = spectrophotometric
Lactic dehydrogenase	7.40	TRIS* 0.1 *M*	Sodium pyruvate 1 m*M*	Diphosphopyridine nucleotide, reduced 1 m*M*	Oxidized diphosphopyridine nucleotide, (F)
Malic dehydrogenase	8.80	TRIS 0.1 *M*	Sodium oxaloacetate 1 m*M*	Diphosphopyridine nucleotide, reduced 1 m*M*	Oxidized diphosphopyridine nucleotide, (F)
Glucose-6-phosphate dehydrogenase	9.48	AMP** 0.1 *M*	Glucose-6-phosphate disodium salt 5 m*M*	Triphosphopyridine nucleotide, oxidized 0.3 m*M* Mg^{++}	Reduced triphosphopyridine nucleotide, (F)
Phosphoglucoisomerase	9.0	TRIS 0.1 *M*	Glucose-6-phosphate disodium salt 90 m*M*	None	Fructose-6-phosphate, (S)
Aldolase	8.6	Hydrazine 60 m*M*	Fructose-1, 6-diphosphate 10 m*M*	Hydrazine	Triose phosphate, (S)
Alkaline phosphatase	10.0	AMP 0.05 *M*	p-nitrophenol phosphate 4 m*M*	Mg^{++}	p-nitrophenol, (S)

* TRIS = Trishydroxymethylaminomethane buffer
** AMP = 2-amino-2-methyl-1,3-propandiol buffer

nification [15,17]. The enlarged area of the sample was measured with a planimeter, and the sample area calculated in square millimeters. The microtome on which the gross sections were cut was adjusted to provide a section of 0.22 millimeter thickness. This constant value was used to calculate the original sample volume prior to lyophilization. The volume of the tissue area was then divided by its weight and the result reported as grams per liter of tissue. Variations resulting from expansion and contraction with temperature variation and a possibility of a systematic error from compression of the tissue during cutting have been disregarded. The values reported in Table II indicate an unusually low water content and may reflect shrinkage error [2,6,15]. The results obtained, however, are reproducible and are included in this work as they may be of interest from a comparative point of view.

Lipid content: Weighed tissue samples were extracted with ethanol and heptane and then reweighed [15]. In other tissues a very high percentage of lipid material is extracted by this procedure [19]. No detectible amount of material was removed from the epiphyseal-plate areas studied by this technique. The method, however, will not detect lipid when it constitutes less than 5 per cent of tissue dry weight.

Solid extracted by acid treatment: Weighed tissue samples dissected from the lyophilized sections were soaked for from seven to ten minutes in 0.1 N hydrochloric acid at room temperature and then dehydrated with ethanol and heptane. The redried sections were reweighed and the weight difference so obtained expressed as acid-soluble solid material. By this procedure bone salts primarily are extracted, as they are freely soluble at low pH [2].

TABLE II

ACID-SOLUBLE SOLID, TOTAL SOLID, AND PHOSPHORUS CONTENT IN THE INDICATED AREAS OF THE DISTAL EPIPHYSEAL PLATE OF A THREE-WEEK-OLD DOG FEMUR*

Location	Total Phosphorus Content (Moles/Kg.)	Total Solid Content (gm./L)	Acid-Soluble Solid Content (gm./Kg. dry weight)
Unorganized cartilage cells	0.015 ± 0.008 (11)	534. ± 32.2 (8)	227. ± 19.9 (5)
Proliferating cartilage cells	0.122 ± 0.092 (4)	472. ± 16.7 (5)	205. ± 44.8 (9)
Hypertrophic cartilage cells	1.51 ± 0.080 (11)	413. ± 37.4 (5)	571. ± 58.2 (4)
Primary spongiosa	2.15 ± 0.118 (11)	849. ± 55.0 (9)	689. ± 42.0 (5)

* Data are expressed in the indicated units ± the standard error of the mean (S.E.M.). The number of determinations in each case is given in parentheses.

Enzyme measurements: All enzyme measurements were carried out in 2-millimeter bore micro test tubes, using tissue samples weighing from 0.8 to ten micrograms. The details of the assay methods have been given previously, and Table I provides a summary of the general procedure followed in each case. Lactic and malic dehydrogenases were determined by the DPN^+ fluorescence method of Lowry [12,16,20,22,23]. Glucose-6-phosphate dehydrogenase also was measured fluorometrically [13]. Phosphoglucoisomerase, aldolase, and total phosphorus were all measured by spectrophotometric methods [2,17,15].

RESULTS

Total and Partial Solid Content

In the epiphyseal plate, large amounts of phosphorus are contained in the zones of hypertrophic cartilage cells and primary spongiosa (Table II). The total phosphorus content in these locations is twenty times greater than in the highly active cellular areas of Ammon's horn in the brain [19]. As calcification advances, the phosphorus content increases from a negligible fraction of the weight of the free and proliferating cartilage-cell area to 4.5 per cent of the hypertrophic-area weight and to 7 per cent of the dry weight in the zone of provisional calcification and primary spongiosa.

The data on the total solid content (Table II) are presented to demonstrate relative changes in tissue density as calcification advances, and, accordingly, are presented in terms of grams of dry solid per liter of wet tissue. As noted previously, the computation of sample volume does not include correction for tissue contraction, expansion, compressibility, or shrinkage. The water content indicated by these data is much lower than reported in other studies of cartilage composition [6]. It is of interest here only because it reflects comparative differences between the different zones of the epiphyseal plate. The figure for the total solid content represents the content of collagen, protein, and bone salts in grams per liter of fresh tissue. The content of total solid progressively decreases as the unorganized cartilage cells mature to form the hypertrophic cartilage-cell area and then doubles as calcium salts are deposited in the primary spongiosa. These quantitative results might be anticipated from the histological appearance of these areas, since the maturing cartilage cells and matrix appear to become swollen prior to the deposition of calcium.

Extraction of the selected areas with ethanol and hexane indicated less than 5 per cent lipid content. This observation is in agreement with macrostudies of lipid content in compact bone by Eastoe and Eastoe. Since as much as 70 per cent of bone dry weight results from its content of inorganic salts, an attempt was made to adjust the enzyme activities measured on a total dry-weight basis to a

TABLE III

ENZYME CONTENT IN AREAS OF THE DISTAL EPIPHYSEAL PLATE FROM THE FEMUR OF A THREE-WEEK-OLD DOG*

Stage	Enzyme Activities				
	Glucose-6-phosphate Dehydrogenase	Lactic Dehydrogenase	Malic Dehydrogenase	Alkaline Phosphatase	Phosphoglucoisomerase
Unorganized cartilage cells	0.0926 ± 0.013 (7)	10.9 ± 1.0 (7)	6.49 ± 0.032 (8)	0.276 ± 0.071 (12)	7.95 ± 0.56 (6)
Proliferating cartilage cells	0.127 ± 0.067 (7)	42.6 ± 1.7 (6)	12.0 ± 0.061 (7)	2.41 ± 0.079 (9)	14.6 ± 1.0 (7)
Hypertrophic cartilage cells	0.182 ± 0.007 (7)	25.5 ± 2.8 (7)	11.8 ± 0.035 (8)	6.75 ± 0.50 (10)	12.2 ± 1.4 (6)
Primary spongiosa	0.381 ± 0.036 (7)	9.44 ± 0.96 (6)	16.4 ± 1.7 (7)	7.51 ± 0.82 (10)	8.37 ± 1.0 (6)

* Activity is expressed as moles of substrate converted or split per kilogram dry weight of tissue per hour ± the standard error of the mean. The number in parentheses indicates the number of determinations in each case.

standard more closely related to actual cellular content. Although not ideal, the weight of material remaining after extraction with 0.1 N hydrochloric acid was used for this purpose. Under this condition bone salt is freely soluble and is removed from the tissue area along with other material soluble in acid [2]. It must be emphasized that, aside from bone salt, exactly what is removed by extraction with 0.1 N hydrochloric acid is unknown. The protein component of the tissue in which the enzyme activity resides is insoluble under this condition. The amount of material extracted by treatment with acid is greatest in the primary spongiosa but is also high in the hypertrophic-cell area. This figure represents primarily the amount of bone salt and related acid-soluble material in the tissues. This information has been used to adjust the enzyme activities based on total dry weight (Fig. 2, Table III) to a value based only on the non-acid soluble material of the area (Fig. 3, Table V).

No attempt was made at this time to compare the total and partial solid or phosphorus content in the three-week-old and newborn animals.

Enzyme studies: The enzyme content on a total dry-weight basis of the selected areas from the epiphyseal plate is below that observed in other active cellular locations. In large part this observation reflects the high content of inorganic salt and inert organic matrix in the epiphyseal plate. In order that a closer ap-

TABLE IV

ENZYME CONTENT IN AREAS OF THE EPIPHYSEAL PLATE FROM THE FEMUR OF A NEWBORN DOG*

Stage	Enzyme			
	Glucose-6-phosphate Dehydrogenase	Lactic Dehydrogenase	Malic Dehydrogenase	Alkaline Phosphatase
Unorganized cartilage cells	0.112 ± 0.010 (6)	11.9 ± 0.74 (7)	9.74 ± 0.94 (7)	0.0640 ± 0.025 (12)
Proliferating cartilage cells	0.152 ± 0.013 (11)	29.6 ± 4.6 (7)	16.3 ± 1.8 (6)	3.53 ± 0.75 (12)
Hypertrophic cartilage cells	0.149 ± 0.024 (8)	22.3 ± 4.1 (6)	14.5 ± 0.82 (7)	5.25 ± 0.72 (17)
Primary spongiosa	0.271 ± 0.028 (12)	8.60 ± 0.53 (7)	16.0 ± 1.2 (7)	6.27 ± 0.76 (14)

* Activity is expressed as moles of substrate converted or split per kilogram dry weight of tissue per hour ± the standard error of the mean. The number in parentheses indicates the number of determinations in each area.

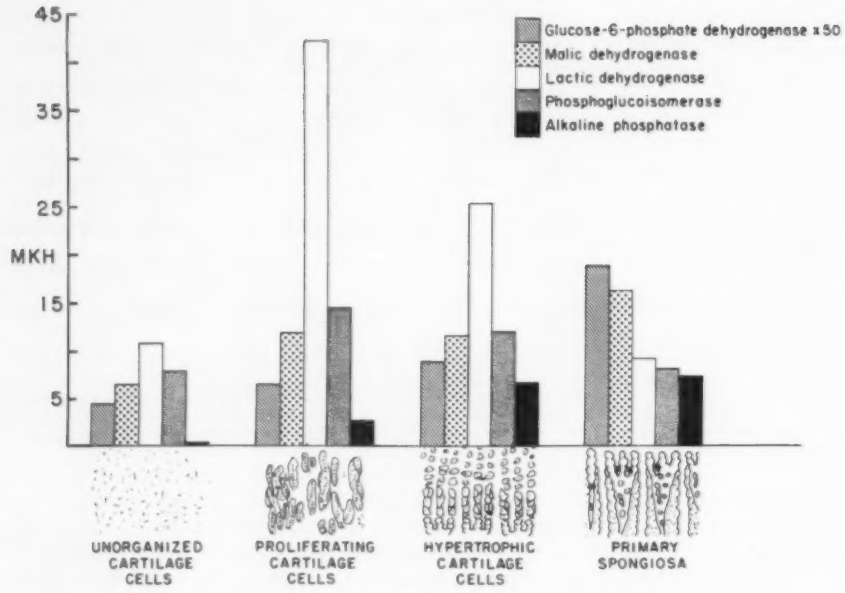

FIG. 2

Enzyme content in areas of the femoral epiphyseal plate of a three-week-old dog. Enzyme activity is expressed as moles of substrate converted per kilogram of total dry weight of tissue. Glucose-6-phosphate dehydrogenase activity has been multiplied fifty times to fit the scale used. Table III provides the statistical details.

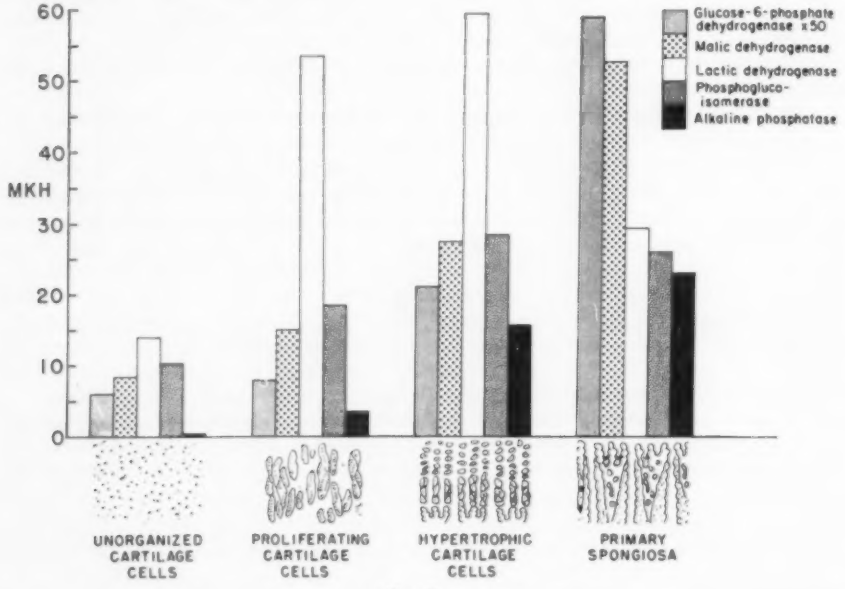

FIG. 3

Enzyme content in areas of the femoral epiphyseal plate of a three-week-old dog, calculated on the basis of non-acid extractable solid content. Enzyme activity is expressed in this case as moles of substrate converted per kilogram of dry weight of non-acid soluble material in the tissue. The tissue was extracted with 0.1 N hydrochloric acid to obtain this information (see text). Glucose-6-phosphate dehydrogenase activity has been multiplied fifty times to fit the scale used.

TABLE V

ENZYME CONTENT IN AREAS OF THE DISTAL EPIPHYSEAL PLATE FROM THE FEMUR OF A THREE-WEEK-OLD DOG, CALCULATED ON THE BASIS OF NON-ACID EXTRACTABLE SOLID *

Stage	Enzyme Activities				
	Glucose-6-phosphate Dehydrogenase	Lactic Dehydrogenase	Malic Dehydrogenase	Alkaline Phosphatase	Phosphoglucoisomerase
Unorganized cartilage cells	0.120	14.1	8.41	0.358	10.3
Proliferating cartilage cells	0.160	53.6	15.1	3.03	18.4
Hypertrophic cartilage cells	0.425	59.5	27.5	15.7	28.4
Primary spongiosa	1.18	29.3	52.7	23.4	26.0

* Activity in this table is expressed as moles of substrate converted per kilogram dry weight of non-acid extractable solid per hour. The data in Tables II and III have been combined to obtain this information.

proximation of the more pertinent cellular enzyme content may be made, the results of the enzymatic studies are considered first on a total-weight basis (Tables III and IV, Fig. 2) and then on the basis of solid not soluble in acid (Table V, Fig. 3).

Lactic dehydrogenase and phosphoglucoisomerase: These two enzymes have a similar relative distribution throughout the epiphyseal area (Tables III and IV, Fig. 2). In both the newborn and the three-week-old animals there is peak activity of these enzymes on a total-weight basis in the proliferating cartilage-cell zone and lower activity in both the unorganized cartilage area and the primary spongiosa. When adjusted for the acid-soluble material contained in the tissue (Table V, Fig. 3) the distribution of both enzymes follows a similar pattern, but reaches peak activity in the hypertrophic cartilage-cell area.

Malic dehydrogenase: Malic dehydrogenase becomes increasingly more active as calcification advances, but has nearly equal activity on a dry-weight basis in the proliferating and hypertrophic cell areas. On the basis of both total and non-acid soluble solid content, malic dehydrogenase increases to have its highest activity in the primary spongiosa.

Aldolase: Aldolase activity was not detected by the colorimetric method used. The limit of sensitivity of the method was 0.5 MKH*.

Glucose-6-phosphate dehydrogenase: This enzyme is interesting because it exhibits only a minor increase of activity in both age groups as maturation of the cartilage proceeds to the formation of the hypertrophic area. As the primary spongiosa develops, however, it then doubles in activity on a total dry-weight basis, and triples on the basis of non-acid soluble solid content.

Alkaline phosphatase: Alkaline phosphatase increases progressively in activity with each advancing stage of calcification to reach a maximum in the zone of provisional calcification (Tables III, IV, and V, Figs. 2 and 3). This transition is most dramatic on a non-acid soluble solid basis, but is also present when the data are considered on the basis of total solid content. The distribution of alkaline phosphatase has been studied extensively, using conventional methods of slide histochemistry, and these results agree with previous reports [1,2]. The activity noted here on a dry-weight basis is ten times greater than that reported by Follis [7]. This

* MKH indicates the number of moles of substrate converted per kilogram of dry weight of tissue per hour.

probably reflects both more favorable assay condition and tissue variations. When consideration is made for the 69 per cent of acid-soluble solid material present in the primary spongiosa area, the alkaline-phosphatase activity is very high, reaching twenty-three MKH (Tables II and V, Figs. 2 and 3). On a total dry-weight basis it has up to four times greater activity than the cellular areas of brain [19].

Although there is some absolute variation in the results obtained from the three-week-old and the newborn animal groups, both sets of observations follow the same general trend and distribution. These differences reflect variation in age and in animals. The over-all picture obtained in comparing the two groups is one of a general increase in enzyme activity with maturation. This observation is similar to the results obtained in other studies of the biochemical alterations associated with growth [13,14].

DISCUSSION

Enzymes mediating carbohydrate metabolism, not only through the Embden-Meyerhoff pathway and citric-acid cycle, but also through the hexosemonophosphate shunt, are present in the epiphyseal plate. The cellular areas of the epiphyseal plate resemble those of brain and retina by having lactic and malic dehydrogenase and phosphoglucoisomerase as three of their most active enzymes [3,13,19,28]. The peak lactic dehydrogenase content in the proliferating and hypertrophic cell areas reflects the avascularity with consequent low oxygen tension of this area and the occurrence of anaerobic glycolysis [20]. In this regard, sheep embryonic cartilage has been observed to produce lactic acid when incubated with glucose under anaerobic conditions [4].

The phosphoglucoisomerase step occurs early in the Embden-Meyerhoff sequence of glucose and glycogen metabolism. The distribution of this enzyme follows that of lactic dehydrogenase, as has been observed in brain and retina [20]. Aldolase, another enzyme of the Embden-Meyerhoff sequence, was not detected. However, this observation probably results from the use of too insensitive an analytical method. Its activity in other tissues is generally far below that of the other enzymes studied [28]. The presence of phosphoglucoisomerase at all stages of endochondral ossification suggests that the Embden-Meyerhoff pathway is prominent in this process.

In the area closest to the blood supply, the primary spongiosa, glucose-6-phosphate dehydrogenase and malic dehydrogenase reach their greatest significance. This may reflect the growing importance of aerobic metabolism through the citric-acid cycle and the direct oxidative pathway as oxygen is made increasingly available by invasion of blood supply into the area.

The activity of alkaline phosphatase in the epiphyseal plate is most noteworthy. On a total dry-weight basis this is the only enzyme which is more active in the epiphyseal plate than in the cellular areas of brain. However, it is more proper to compare the specific enzyme activity present in the epiphyseal plate with that in other locations after some correction has been made for its relative content of enzymatically inert bone salt and other acid-soluble material. When considered on the basis of acid-insoluble solid material, alkaline-phosphatase activity increases in the hypertrophic and primary spongiosa areas to levels greater than those reported previously (Table V, Fig. 3). The largest amount of alkaline phosphatase previously described was present in the proximal convoluted tubule area of the kidney, where using an identical method of analysis, activities of from twelve to fourteen MKH fat-free dry weight were observed [26]. The data for alkaline-phosphatase activity in the proximal convoluted tubule area of the kidney has included a correction for its sizable lipid content of bone. By making this consideration and the one for bone salt, a more realistic comparison can be made between the two tissues. It is interesting that the greatest alkaline-phosphatase activity is present in the two areas of the plate which contain the greatest

amount of phosphorus. Much evidence has been presented concerning the role of alkaline phosphatase in calcification, and this has been extensively reviewed by others [27].

The enzyme content in the epiphyseal plate on a total weight basis is somewhat lower than has been described in other metabolically active cellular areas in the brain, retina, cornea, and kidney [12,14,16,19,20,26,28]. When adjusted for their content of bone salt and other acid-soluble material, however, the epiphyseal areas have comparable enzyme activity. The enzyme content on a total weight basis in the epiphyseal plate increases as the whole animal matures. These observations suggest that the cells participating in the development of endochondral bone are actively metabolizing carbohydrate through recognized pathways. Moreover, changes occur in these pathways that reflect morphological differentiation of the elements comprising the epiphyseal plate and the deposition of tissue.

SUMMARY

Preliminary information of the general enzymatic characteristics of the normal stages of the development of endochondral bone in the dog and the effect of age are presented. The enzymes glucose-6-phosphate, lactic and malic dehydrogenase, and phosphoglucoisomerase are found to be active through the maturing stages of epiphyseal development. Alkaline-phosphatase activity, on the basis of acid-insoluble material comprising the area, is greater in the primary spongiosa than in other locations, as reported previously. The results are discussed in relation both to the total and the acid-soluble solid and phosphorus content in the areas. An over-all increase in the level of enzyme activity is noted in the epiphyseal plate as the newborn dog matures.

The enzyme content in the epiphyseal plate is such as to indicate that the process of epiphyseal growth and bone formation is an enzymatically regulated sequence deriving energy and intermediates through the Embden-Meyerhoff pathway, the hexosemonophosphate shunt, and the tricarboxylic-acid cycle. Adaptations of microchemical techniques suitable for chemical investigation of biopsy material from diseased epiphyseal plates are presented.

REFERENCES

1. Bourne, G. H.: The Distribution of Alkaline Phosphatase in Various Tissues. Quart. J. Exper. Physiol., **32:** 1-20, 1943.
2. Bourne, G. H.: The Biochemistry and Physiology of Bone. Chaps. 3–12, pp. 53–325. New York, Academic Press Inc., 1956.
3. Buell, M. V.; Lowry, O. H.; Roberts, N. R.; Chang, M. W.; and Kapphahn, J. I.: The Quantitative Histochemistry of the Brain. V. Enzymes of Glucose Metabolism. J. Biol. Chem., **232:** 979–993, 1958.
4. Cartier, Pierre: Les constituants minéraux des tissus calcifiés. V. Les anions organiques de l'os. Bull. Soc. Chim. Biol., **33:** 161–169, 1951.
5. Eastoe, J. E., and Eastoe, B.: The Organic Constituents of Mammalian Compact Bone. Biochem. J., **57:** 453–459, 1954.
6. Eichelberger, Lillian; Akeson, W. H.; and Roma, Michael: Biochemical Studies of Articular Cartilage. I. Normal Values. J. Bone and Joint Surg., **40-A:** 142–152, Jan. 1958.
7. Follis, R. H., Jr.: Studies on the Chemical Differentiation of Developing Cartilage and Bone. I. General Method. Alkaline Phosphatase Activity. Bull. Johns Hopkins Hosp., **85:** 360–369, 1949.
8. Follis, R. H., Jr., and Berthrong, Morgan: Histochemical Studies on Cartilage and Bone. I. The Normal Pattern. Bull. Johns Hopkins Hosp., **85:** 281–298, 1949.
9. Gutman, A. B., and Gutman, E. B.: A Phosphorylase in Calcifying Cartilage. Proc. Soc. Exper. Biol. and Med., **48:** 687–692, 1941.
10. Gutman, A. B.; Warrick, F. B.; and Gutman, E. B.: Phosphorylative Glycogenolysis and Calcification in Cartilage. Science, **95:** 461–462, 1942.
11. Gutman, A. B., and Yu, T. F.: A Concept of the Role of Enzymes in Endochondral Calcification. *In* Metabolic Interrelations, Transactions of the Second Conference, pp. 167–190. Edited by Edward C. Reifenstein, Jr. New York, Josiah Macy, Jr. Foundation, 1950.
12. Kuhlman, R. E.: Species Variation in the Enzyme Content of the Corneal Epithelium. J. Cell. Comp. Physiol., **53:** 313–326, 1959.
13. Kuhlman, R. E., and Lowry, O. H.: Quantitative Histochemical Changes During the Development of the Rat Cerebral Cortex. J. Neurochem., **1:** 173–180, 1956.
14. Kuhlman, R. E., and Resnik, R. A.: Quantitative Histochemical Changes in the Development of the Rat Lens and Cornea. Am. J. Ophthal., **46:** 47–55, 1958.

15. Lowry, O. H.: The Quantitative Histochemistry of the Brain. Histological Sampling. J. Histochem. and Cytochem., **1:** 420–428, 1953.
16. Lowry, O. H.: Enzyme Concentrations in Individual Nerve Cell Bodies. *In* Metabolism of the Nervous System, pp. 323–328. Edited by Derek Richter. New York, Pergamon Press, Inc., 1957.
17. Lowry, O. H.; Roberts, N. R.; Leiner, K. Y.; Wu, Mei-Ling; and Farr, A. L.: The Quantitative Histochemistry of Brain. I. Chemical Methods. J. Biol. Chem., **207:** 1–17, 1954.
18. Lowry, O. H.; Roberts, N. R.; Wu, Mei-Ling; Hixon, W. S.; and Crawford, E. J.: The Quantitative Histochemistry of Brain. II. Enzyme Measurements. J. Biol. Chem., **207:** 19–37, 1954.
19. Lowry, O. H.; Roberts, N. R.; Leiner, K. Y.; Wu, Mei-Ling; Farr, A. L.; and Albers, R. W.: The Quantitative Histochemistry of Brain. III. Ammon's Horn. J. Biol. Chem., **207:** 39–49, 1954.
20. Lowry, O. H.; Roberts, N. R.; and Lewis, Charles: The Quantitative Histochemistry of the Retina. J. Biol. Chem., **220:** 879–892, 1956.
21. Lowry, O. H.; Roberts, N. R.; and Chang, M. W.: The Analysis of Single Cells. J. Biol. Chem., **222:** 97–107, 1956.
22. Lowry, O. H.; Roberts, N. R.; and Kapphahn, J. I.: The Fluorometric Measurement of Pyridine Nucleotides. J. Biol. Chem., **224:** 1047–1064, 1957.
23. Lowry, O. H.; Roberts, N. R.; Lewis, C.; and Atchison, A.: To be published.
24. Marks, P. A.; and Shorr, Ephraim: A Method for Evaluating the Relation of Glycogen to Inorganic Salt Deposition in Surviving Cartilage Slices *in Vitro*. Science, **112:** 752–754, 1950.
25. Maximow, A. A., and Bloom, William: A Textbook of Histology. Ed. 6, pp. 126–158. Philadelphia, W. B. Saunders Co., 1952.
26. McCann, W. P.: Quantitative Histochemistry of the Dog Nephron. Am. J. Physiol., **185:** 372–376, 1956.
27. Moog, Florence: Physiological Significance of the Phosphomonoesterases. Biol. Revs. Cambridge Phil. Soc., **21:** 41–59, 1946.
28. Robins, Eli; Smith, D. E.; Eydt, K. M.; and McCaman, R. E.: The Quantitative Histochemistry of the Cerebral Cortex. II. Architectonic Distribution of Nine Enzymes in the Motor and Visual Cortices. J. Neurochem., **1:** 68–76, 1956.
29. Robison, Robert, and Rosenheim, A. H.: Calcification of Hypertrophic Cartilage *in Vitro*. Biochem. J., **28:** 684–698, 1934.
30. Rubin, P. S., and Howard, J. E.: Histochemical Studies on the Role of Acid Muco-Polysaccharides in Calcifiability and Calcification. *In* Metabolic Interrelations, Transactions of the Second Conference, pp. 155–166. Edited by Edward C. Reifenstein, Jr. New York, Josiah Macy, Jr. Foundation, 1950.

Flexor Pollicis Longus Muscle

Its Morphology and Clinical Significance

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In man the flexor pollicis longus is an important muscle for function of the hand. It is absent in some primates, such as the gorilla and chimpanzee, but there is a well developed flexor hallucis longus which performs the same function as the flexor pollicis longus in man. In the hand of some primates there is a vestige of the flexor pollicis longus which is lost in the mass of the flexor digitorum profundus, but the phalanges of the thumb in these animals do not show the depression for the flexor pollicis longus observed in man. Other primates, such as the tarsiers—*Nycticebus tardigradus*, for example—possess a well developed flexor pollicis longus.

It is probable that the flexor pollicis longus muscle is a comparatively recent acquisition in the evolution of the hand. The study of its morphology is interesting from many viewpoints, especially since it has definite clinical significance in injuries and surgical approaches around the elbow joint.

It must be kept in mind that the multiple arrangements of the flexor pollicis longus observed in primates can be observed as variations in man. This has been brought out by the studies of many anatomists, especially Testut. These variations are numerous, consisting of different, more or less intimate connections with the common flexor muscles of the fingers, especially in the flexor profundus. In primates the absorption of the flexor pollicis longus into the muscle mass of the flexors results in loss of the functional independence of the thumb flexor.

It is known that in man the flexor pollicis longus usually has, in addition to its main origin, a muscle belly (sometimes referred to as Gantzer's muscle) which may originate either from the coronoid process of the ulna or from the medial epicondyle of the humerus, where it is separated from the muscle mass of the flexor digitorum sublimis. This additional muscle mass runs distally and obliquely parallel to the ligament of Weitbrecht (chorda obliqua) to join the principal head and its tendon.

It is the purpose of the present study to determine the incidence and variations of this accessory muscle and to investigate the distribution of the nerve supply to the flexor pollicis longus muscle.

Materials and Method

Seventy-six forearms were investigated, of which six belonged to premature infants. In thirty-four cadavera it was possible to observe both upper extremities so that comparative studies could be made of sixty-eight right and left extremities.

In doing the anatomical dissections of the flexor pollicis longus and its adjoining structures a long incision on the volar aspect of the forearm was made from the wrist at the insertion of the tendon of the flexor carpi radialis to the elbow over the origin of the same muscle. The incision was extended in a bayonet fashion up the arm to the medial side of the long head of the biceps to obtain a good view of the nerve supply. The flexor carpi radialis was separated from the radial artery and the palmaris longus in the distal part of the forearm and from the pronator teres in the proximal part. After the flexor sublimis of the fingers was reflected, the median nerve was exposed throughout its course as far as the wrist. This exposure gave a complete view of the flexor pollicis longus.

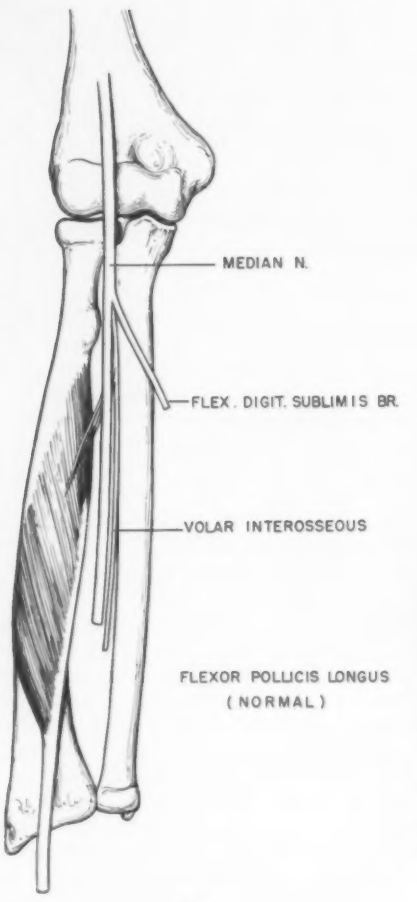

FIG. 1

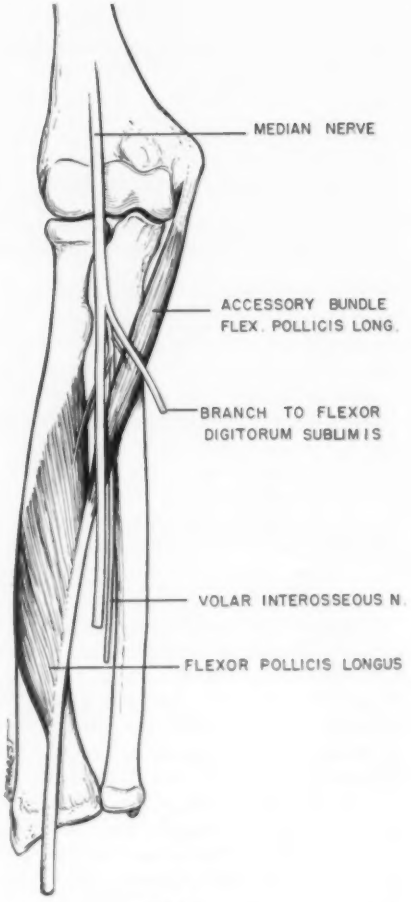

FIG. 2

Fig. 1: The "normal" arrangement of the flexor pollicis longus muscle, which consists of a belly originating from the interosseous membrane and the anterior surface of the middle third of the radius, with fleshy fibers directed obliquely downward to join the tendon. The innervation is by one, or frequently two branches from the anterior interosseous nerve, which enter the muscle at a constantly high level.

Fig. 2: In thirty-four instances (61 per cent) the accessory head of the flexor pollicis longus took origin from the medial epicondyle of the humerus in common with the mass of the flexors of the fingers. In the majority of instances this accessory head is innervated by a branch of the anterior interosseous nerve. The accessory belly is located between the median nerve and the anterior interosseous nerve. As illustrated here, in certain instances the tendon of the flexor pollicis longus appears as a direct continuation of the accessory belly.

The Flexor Pollicis Longus

The main portion of this muscle, which is composed of fleshy fibers, takes origin from the upper third of the radial diaphysis and the interosseous membrane and is directed obliquely and distally toward the ulnar side of the forearm (Fig. 1). Its tendon starts at the level of the junction of the proximal and middle thirds of the forearm. The flexor pollicis longus lies at the same depth as the flexor profundus of the fingers and is separated from the profundus muscle by the anterior interosseous nerve and artery which lie between the two muscles. The deeper fibers of both muscles converge to take origin from the interosseous membrane.

The flexor pollicis longus receives its innervation constantly through the an-

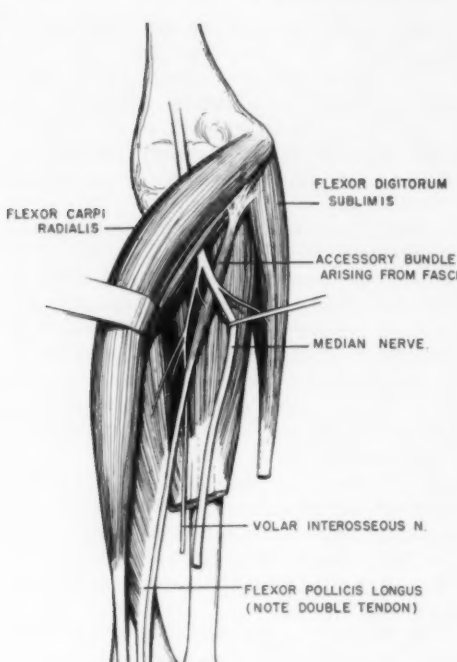

FIG. 3

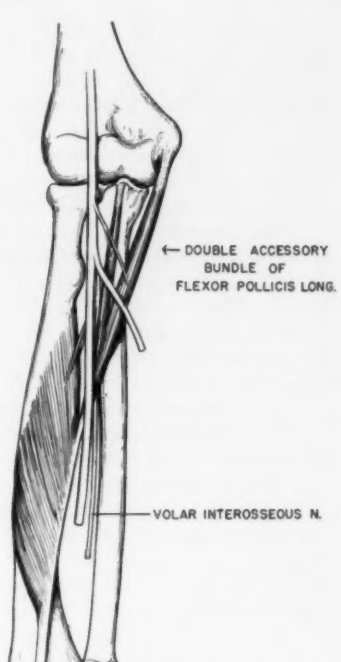

FIG. 4

Fig. 3: In five instances (9 per cent) the accessory head took origin from the intermuscular fascia. As illustrated, sometimes the tendon of the flexor pollicis longus is doubled; the two parts seem to belong to the main and the accessory parts of the muscle.

Fig. 4: In twelve instances (22 per cent) the accessory head took origin from the coronoid process of the ulna. In a few instances I observed two accessory heads that originated from the coronoid process of the ulna and the medial epicondyle of the humerus, respectively. In a few instances the innervation of the accessory heads was from a separate branch of the accessory nerve.

terior interosseous nerve. A branch from this nerve runs obliquely toward the muscle to enter it on the volar aspect of its fleshy portion about two centimeters proximal to the origin of the tendon, which extends distally from a point located approximately at the junction of the upper and middle thirds of the muscle belly. In about 70 per cent of the cases studied, another nerve branch from the anterior interosseous nerve originated at a point slightly distal to the first branch and entered the muscle on its dorsal aspect, almost at the same level as the other branch.

Accessory Head

In the seventy-six upper extremities studied, the accessory head was encountered fifty-six times (74 per cent). If, however, I were to consider the instances in which I found accessory heads in both upper extremities of the same cadaver, the incidence would be 62 per cent. Thus, it appears that the accessory head was present in almost two-thirds of the arms studied, making it, therefore, a really normal occurrence.

In the fifty-six instances just mentioned, the accessory head was found to take origin from the medial epicondyle of the humerus in association with the common origin of the forearm flexors thirty-four times (61 per cent); from the

coronoid process of the ulna twelve times (22 per cent); from the intermuscular fascia between the flexor sublimis and profundus five times (9 per cent); and from a double origin—the medial epicondyle and the coronoid process—three times (5 per cent). One of the double origins was found in a premature infant.

The accessory head which arises from the medial epicondyle of the humerus always runs obliquely toward the lateral or radial side of the arm. Its diameter varies from 0.5 centimeter to two centimeters, the latter size in the arms in which it is most highly developed.

The accessory head always lies between the median nerve anteriorly and the anterior interosseous nerve posteriorly (Fig. 2).

The accessory head was almost constantly innervated by a branch from the anterior interosseous nerve. In only four instances (7 per cent) were the accessory head or heads supplied by one or two nerve branches that derived directly from the median nerve. In all instances, whether the innervation came from the interosseous or median nerve, the direct branch to the accessory head entered this portion of the muscle at a level proximal to the origins of the nerve branches to the main mass of the muscle and proximal to the origins of the other muscular branches given off by the anterior interosseous nerve.

The relationship of the fleshy fibers of the main belly of the flexor pollicis longus to the tendon of the accessory head was of interest. In five instances (9 per cent) the combined tendon appeared to be a continuation of the accessory belly, rather than of the main muscle. In nineteen instances (34 per cent) the tendon seemed to be double, as if it were separated into two parts, one from the main belly and one from the accessory head.

In two instances a muscle belly, which at first appeared to be an accessory belly, was found to be the flexor profundus indicis. In these two instances the flexor pollicis longus had no accessory belly.

It is not surprising to find that there are many variations in the manner in which the flexor pollicis longus and the flexor digitorum profundus are combined, because both have a common phylogenic derivation from the pronatoflexor group of Humphry. On the other hand, it is difficult from a comparative anatomical viewpoint to explain why this muscle exists almost exclusively in man and is absent in other species.

DISCUSSION

The nerve or nerves that supply the flexor pollicis longus muscle enter the belly near the elbow, whereas the motor point of the flexor pollicis longus is situated on the volar surface of the forearm at the junction of the lower third with the middle third, near the lateral border of the radius. The location of the motor point is not a guide to the actual location of the nerves to the flexor pollicis longus. Since the accessory muscle belly is frequently present, afflictions of this portion of the muscle must be borne in mind in instances of functional disability and contracture of the distal phalanx of the thumb, when the level of the injury does not correspond to the area of the normal origin of the flexor pollicis longus. Kaplan [2] reported a case of flexion contracture of the thumb in which the disability had been present for eleven years after the patient had fractured and dislocated his left elbow. The deformity was found to be due to a cicatricial contraction of the accessory belly of the flexor pollicis longus at its origin, a consequence of injury to the elbow. The contraction was successfully corrected by simple tendon elongation of the flexor pollicis longus at the wrist.

Similarly, the possibility of an accessory belly of the flexor longus pollicis muscle being present must be kept in mind in operations performed in the anterior region of the elbow to avoid injury to it, with resultant secondary contractures of the flexor pollicis longus.

(References are on page 559)

Conservative Treatment of Impacted Fractures of the Femoral Neck

A Report of Fifty Cases*

BY HENRY B. CRAWFORD, M.D., ROCHESTER, NEW YORK

It has long been recognized that many impacted fractures of the femoral neck will do well with any kind of treatment. In 1925 Whitman recommended a plaster spica as treatment for all femoral-neck fractures, but considered that the impacted fracture had a good prognosis. Key and Conwell advised bedrest and non-weight-bearing by immobilization in a plaster boot with a crossboard in the plaster to prevent external rotation, by sandbags with a pillow under the knee, or by light traction. Linton [3], in reporting a series of thirty-one impacted femoral-neck fractures treated by various methods, including plaster casts, traction, bedrest, and fixation with a Smith-Petersen nail, said there were only two bad results. Both of these resulted from displacement of the femoral head during the insertion of the nail. In a later paper Linton said that an impacted fracture was not necessarily stable [4].

Watson-Jones, in his discussion of femoral-neck fractures, said: "Pauwels has shown that the two types are to be distinguished not only by the abduction or adduction displacement of the distal fragment, but also by the plane of fracture. Abduction injuries produce a line of fracture which is almost horizontal and therefore free from shearing strain, whereas adduction injuries cause a more nearly vertical line of fracture which is subject to shearing strain from the transmission of body weight and the effect of muscle retraction." By measuring the angle between the line of fracture and the horizontal line (now called Pauwels' angle) through both anterosuperior iliac spines, Pauwels distinguished three types of femoral-neck fractures and the prognosis in each: In Type I the angle was less than 30 degrees and the fracture united solidly even without treatment (Fig. 1). In Type II the angle was between 30 degrees and 50 degrees and the fracture did not unite unless the shearing strain was prevented by internal fixation (Fig. 2). In Type III the angle was between 50 degrees and 90 degrees, the plane of the fracture being vertical. The effect of the shearing strain here was considered to be so great that even internal fixation might fail (Fig. 3).

The term *abduction injuries* or *abduction fractures* as it is used in the literature usually refers to those impacted fractures in which there is a relative abduction of the femoral shaft caused by the valgus displacement of the femoral head. However, none of the fractures of this type included in this series were due to a true abduction of the limb. They were caused by a direct fall on the trochanter, impacting the femoral neck into the femoral head.

Although conservative treatment for this type of fracture is often considered, remarkably few series of any significance have been reported. Therefore, the purpose of this paper is to record a series of carefully selected impacted subcapital fractures of the femoral neck treated by early mobilization without fixation and to consider the significance of Pauwels' angle in these impacted fractures and the incidence of avascular necrosis.

CLINICAL MATERIAL

Since 1937 my associates and I have seen 393 fractures of the femoral neck. Of these, fifty were diagnosed as impacted and were treated by early mobilization

* Read in part at the Annual Meeting of The American Orthopaedic Association, Hot Springs, Virginia, June 24, 1957.

FIG. 1

FIG. 2

FIG. 3

Fig. 1: Impacted abduction fracture of the femoral neck classified in Pauwels' Type II group. All seventeen fractures in this group united solidly without fixation.

Fig. 2: Impacted abduction fracture of the femoral neck classified in Pauwels' Type II group. Of the twenty-eight fractures in this group, twenty-three united solidly without fixation. Four became disimpacted; they were nailed with resultant solid union. In one there was apparent union four months after injury, although this could not be proved since the patient did not bear weight on the limb after treatment started. (This patient died six months after injury.)

Fig. 3: Impacted abduction fracture of the femoral neck classified in Pauwels' Type III group. Of the five fractures in this group, there was solid union in three. Two patients died before full weight-bearing was allowed, but position was maintained in both of these fractures, with apparent delayed union in one.

without fixation. It should be emphasized at the outset that the fifty patients with these fractures were carefully selected on the basis of both roentgenological and clinical evidence. All exhibited definite evidence of a real impaction in both the anteroposterior and the lateral roentgenograms (Fig. 4), and all showed clinical evidence of stability of the fracture as indicated by the ability to flex and internally rotate the hip actively with minimum discomfort. In addition, the history frequently indicated that the patient had been able to walk on the injured extremity after the accident that had caused the fracture.

It should be stressed that when examining any suspected femoral-neck fracture passive external rotation should not be attempted, even though this is often done when the affected limb is put in the frog-leg position to obtain a lateral roent-

FIG. 4

Anteroposterior and lateral roentgenograms (made in external rotation) of a well impacted fracture of the femoral neck.

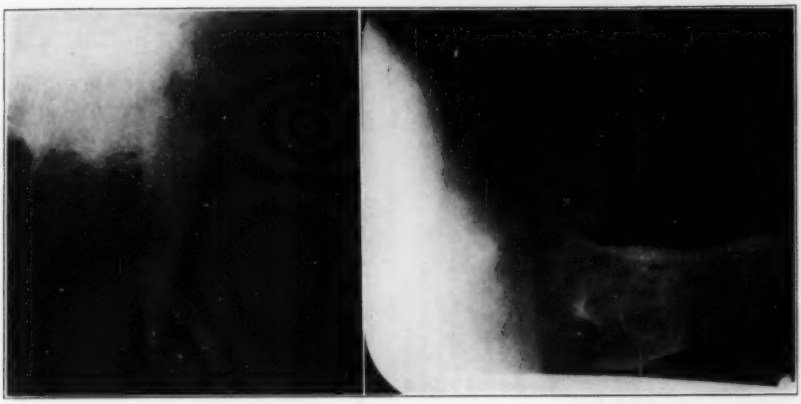

FIG. 5

Fracture of the femoral neck showing shortening and external rotation. This type of fracture should be reduced and nailed immediately.

genogram of the hip. Many of the lateral roentgenograms in this series were made in this way. However, it is much safer to obtain a true lateral view by placing the cone under the uninvolved limb with the patient on his back, directing it at the groin of the affected hip. The cone should form an angle of about 30 degrees with the shaft of the femur and be directed to a point mid-way between the greater trochanter and the crest of the ilium on the skin on the affected side. The cassette should then be held with one edge pressed tightly into the flank just above the iliac crest, with the plane of the cassette parallel to that of the fractured femoral neck and perpendicular to the cone.

It is to be stressed that the fracture is not considered impacted if the anteroposterior roentgenogram demonstrates varus position of the head and separation of the femoral head and neck superiorly, or the lateral roentgenogram demonstrates marked separation of the fragments anteriorly. In the presence of either of these findings the fracture is reduced and internally fixed, regardless of the clinical findings (Fig. 5).

TREATMENT

If the history, the physical examination, and the roentgenographic study of the patient indicate that the fracture is firmly impacted, the situation is discussed thoroughly with the patient and family. It is explained that this type of fracture, if treated with extreme care, may unite without operation or any type of fixation. The advantages of early mobilization and the avoidance of the possible complications which may accompany operation or prolonged bedrest are pointed out. It is also emphasized that with continued activity the fracture may become disimpacted, necessitating reduction and fixation by nailing. In my experience there has been no difficulty in persuading patients to avoid an operation. Furthermore, because they were psychologically prepared, the few patients whose fractures did become disimpacted accepted operation without difficulty.

The patient is told that she must treat the injured limb as she would a valued teacup with a crack in it. It is emphasized that even if discomfort disappears, this attitude must be maintained for at least four months, or longer, until the fracture has united. This idea is re-emphasized by painting the word *fragile* with methylene blue on the affected thigh.

The nurses and the family are shown how to help the patient in and out of bed; the knees must be kept together to avoid any rotation of the affected limb. When the patient sits, she is encouraged to sit with her knees bent and her feet on the floor because this decreases the pull of the hamstring muscles. This position

TABLE I

Fifty Fractures of the Femoral Neck

Case No. and Name	Age (*Years*)	Date of Injury	Weight-Bearing Since Injury	Pauwels' Angle (*Degree*)	Position on Roentgenogram: Anteroposterior	Lateral	Crutch-Walking Started	Full Weight-Bearing	Aseptic Necrosis	Nailed	Result	Time Required for Union	Length of Follow-up
1. S. M.	76	4- 1-37	Yes	35	Valgus	Post. impaction	5-13-37	6-20-37	0	0	Excellent; walks without limp or pain; normal motion	10 wks.	8 yrs.
2. A. B.	77	8-24-39	0	35	Valgus	Post. impaction	9- 1-39	No note	0	0	Good; telephone report: walks without limp or pain (not examined)	6 mos.	1 yr.
3. R. B.	55	3-15-40	0	50	Valgus	Post. impaction	5- 8-40	8-12-40	0	0	Excellent; walks without limp or pain; normal motion	5 mos.	3 yrs.
4. D. T.	42	8-28-43	Yes	45	Valgus	No angle	9- 9-43	1- 5-44	0	0	Excellent; walks without limp or pain; normal motion	5 mos.	15 yrs.
5. M. B.	73	10-16-43	Yes	28	Valgus	Post. impaction	10-17-43	4-18-44	Yes	0	Fair, limps; limitation of flexion and rotation; no pain	6 mos.	5 yrs.
6. M. B.	55	2- 6-44	Yes	33	Valgus	Post. impaction	2- 9-44 (disimpacted)	5-15-44	0	Yes	Excellent; walks without limp or pain; normal motion	6 mos.	13 yrs.
7. C. B.	60	5-27-44	Yes	20	Valgus	No angle	6-12-44	8-16-44	0	0	Excellent; walks without limp or pain; normal motion	3 mos.	14 yrs.
8. S. M.	63	8-16-44	0	30	Valgus	Post. impaction	8-19-44	11-16-44	0	0	Good; occasional limp; limitation of int. rotation; no aseptic necrosis	3 mos.	4 yrs.
9. E. W.	55	12-28-44	Yes	35	Valgus	Ant. separation	1-10-45	3-28-45	0	0	Excellent; no pain or limp; sl. limitation int. rotation and flexion	4 mos.	3 yrs.
10. C. H.	65	1-18-45	0	47	Valgus	No angle	1-22-45	4-19-45	0	0	Excellent; no pain or limp; no limitation of motion	4 mos.	12 yrs.
11. M. E.	69	2- 3-45	0	42	Valgus	No angle	2-13-45	5-15-45	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	3 yrs.
12. A. S.	50	4-25-45	0	30	Valgus	Post. impaction	5-10-45	8- 7-45	Moderate	0	Good; rheu. arth.; less pain in this hip than in either knee	4 mos.	5 yrs.
13. V. M.	48	6- 4-45	0	5	Valgus	No angle	6-19-45	8-19-45	0	0	Excellent; no pain or limitation of motion; polio. limp	3 mos.	3 yrs.
14. W. F.	77	9- 6-45	0	50	Valgus	No angle	9- 6-45	4- 6-46	0	0	Excellent; no pain or limp; no limitation of motion	7 mos.	2½ yrs.
15. M. T.	61	9-20-45	0	40	Valgus	Post. impaction	9-22-45	1-26-45	0	0	Excellent; no pain or limp; no limitation of motion	4 mos.	3 yrs.
16. F. P.	88	11-24-45	0	50	Valgus	No angle	1-26-46	1-17-47	0	Yes	Excellent; no pain or limp; no limitation of motion; used crutches	14 mos.	3 yrs.
17. E. F.	77	10-13-46	Yes	61	Varus	Ant. separation	1- 6-47	9-16-47	0	0	Good; no pain in hip; walks with cane; no limitation of motion	9 mos.	2 yrs.
18. C. N.	76	12-17-46	0	62	Varus	Post. impaction	1- 5-47 (died of cancer 4 months after fracture; hip in good position)						
19. J. R.	36	4- 3-47	0	35	Valgus	No angle	4-10-47	7-17-47		0	Excellent; no pain or limp; no limitation of motion	10 wks.	11 yrs.
20. A. E.	52	5- 1-47	0	40	Valgus	No angle	5- 1-47	7-24-47	0	0	Excellent; no pain or limp; no limitation of motion	4 mos.	10 yrs.
21. F. B.	69	8-22-47	0	20	Valgus	Ant. separation	No note	11-11-47	0	0	Excellent; no pain or limp at end of one year	?	1 yr.
22. E. G.	79	4- 5-48	0	38	Valgus	No angle	6-15-48	9- 7-48	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	5 yrs.
23. A. B.	78	10-30-48	0	60	Valgus	Ant. separation	10-20-48	2-19-49	0	0	Excellent; no pain or limp	6 mos.	5 yrs.
24. R. D.	72	1- 8-49	0	25	Valgus	No angle	1-11-49	4- 7-49	0	0	Excellent; telephoned: no complaints; no pain or limp at 1 yr.	4 mos.	1 yr.

25. L. C.	61	12–30–49	0	35	Valgus	Ant. separation	3–23–50	6–22–50	0	0	Excellent; no pain or limp; very slight limitation of flexion	6 mos.	9 yrs.
26. K. H.	76	10–16–50	0	35	Valgus	Post. displacement and impaction	10–24–50	3–27–51	0	0	Excellent; no pain or limp; no limitation of motion	5 mos.	8 yrs.
27. H. L.	62	6– 9–51	Yes	24	Valgus	No angle	6–20–51	9–27–51	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	5 yrs.
28. A. B.	60	8–20–51	0	30	Valgus	Post. impaction	8–30–50	3– 1–51	Yes	0	Excellent; no trouble, 3 yrs.; then intertroch. fract. followed by asept. necr.	6 mos.	7 yrs.
29. J. S.	72	9–21–51	Yes	50	Valgus	Ant. impaction	9–24–51	12– 4–51	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	5 yrs.
30. M. D.	55	1–16–53	Yes f.w.b.	42	Valgus	Post. impaction	1–16–53	5–16–53	0	0	Excellent; no pain or limp; no limitation of motion	5 mos.	5 yrs.
31. M. S.	71	4–24–53	Yes	30	Valgus	Post. impaction	4–24–53	7–24–53	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	5 yrs.
32. M. S.	56	4–24–53	0	33	Valgus	No angle	4–29–53	7–23–53	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	5 yrs.
33. C. T.	85	7– 8–53	0	30	Valgus	No angle	Wheel chair	9–14–53	0	0	Excellent; no pain or limp; no limitation of motion	6 mos.	1 yr.
34. R. S.	61	3–13–54	Yes	60	Valgus	No angle	3–25–54	8– 3–54	0	0	Excellent; no pain or limp; no limitation of motion	5 mos.	10 mos.
35. E. H.	46	12–21–54	Yes	32	Valgus	No angle	12–21–54	3–19–55	0	0	Excellent; telephone report: excellent function without pain	3 mos.	6 mos.
36. E. S.	52	1–21–55	0	25	Valgus	No angle	2– 2–55	5–16–55	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	3 yrs.
37. E. R.	80	4– 7–55	0	30	Valgus	Post. impaction	Seen by me with Dr. Parke in Albion; treatment outlined and followed by Dr. Parke; Dr. Parke reports in Nov. 1955: result excellent						
38. A. B.	65	4– 1–55	No	35	Valgus	Post. impaction	1–13–55	8–18–55	0	0	Excellent		
39. E. T.	83	6– 1–55	0	57	Valgus	No angle	Wheel chair only; still no evidence of union; position maintained				Died of coronary occlusion 1–21–56; X-rays 6 mos. after inj. showed maintenance of position; union probably not solid		
40. C. G.	75	11– 7–55	Yes	35	Valgus	No angle	Wheel chair because of feebleness; apparent union, 1–6–56				Died 6 mos. after injury; never walked but had free motion and obliteration of fract. line by X-ray 4 mos. after fracture		
41. M. K.	70	4–27–56	0	40	Valgus	No angle		7–20–56	0	0	Excellent; no pain or limp; no limitation of motion	3 mos.	2 yrs.
42. E. H.	66	9– 8–56	0	35	Valgus	No angle	9–12–56	3–17–57	0	0	Excellent; no pain or limp; no limitation of motion	6 mos.	2 yrs.
43. T. J.	70	4– 7–57	0	30	Valgus	No angle	4–14–57	7– 3–57	0	0	Excellent; no pain or limp; sl. limitation of int. rotation and flexion	3 mos.	1 yr.
44. K. F.		6–30–57	0	45	Valgus	No angle	Separated 7– 9–57	2– 8–58	0	7–10–57	Excellent; no pain or limp; no limitation of motion		1 yr.
45. H. T.	60	7–17–58	Yes	50	Valgus	No angle	Separated 7–25–58 with fall	7–18–58 first	0	7–25–58	Excellent; no limp; full motion; discomfort with pressure over head of nail	6 mos.	1½ yrs.
46. M. D.	82	11– 1–58	0	27	Valgus	Post. impaction	11–13–58	4– 1–59	0	0	Excellent; no pain or limp; sl. limitation of internal rotation	5 mos.	7 mos.
47. H. H.	72	2–23–59	0	47	Varus	Post. impaction	2–24–59	5–15–59	0	0			
48. E. E.	72	5–23–59	0	32	Valgus	Post. impaction	6– 2–59	10–24–59	0	0	Complaining of low back pain		
49. E. M.	61	6–15–59	0	30	Valgus	Post. impaction	6–20–59	10–22–59	0	0	Telephone report 2–5–60: no pain or limp; "100%"	4 mos.	8 mos.
50. C. M.	83	10–17–59	0	25	Valgus	No angle	10–26–59	3–10–60	?	0	Union; excellent motion in hip without pain	less than 5 mos.	5 mos.

also excludes the tendency of the leg to go into external rotation, which occurs when the knee is extended and the foot elevated while the patient is sitting.

As soon as the patient's comfort and agility allow, she is taught to use crutches or a walker without bearing weight on the affected limb. The involved limb is allowed to rest on the ground during the stance phase. She continues to walk this way for at least four months or until roentgenograms of the fracture show evidence of union.

All patients were discharged from the hospital as soon as they were able to walk confidently on crutches. A few feeble patients were allowed up in a chair, but were not allowed to walk with crutches until the fractures had united. Three patients were too feeble ever to bear full weight on the affected limb.

RESULTS

Healing of the fracture was considered to be present when the patient was able to bear full weight without discomfort and roentgenograms did not exhibit any translucency at the fracture site four months or more after injury.

In this series of fifty impacted fractures, forty-three healed with conservative treatment. These forty-three patients were followed for a minimum of four months and a maximum of fifteen years after injury; the mean follow-up was three and one-half years.

Three patients died without having borne full weight on the affected limb:

Case 18 died of cancer within six months of injury. Her last roentgenograms, made eight weeks after injury, exhibited the same position of impaction present immediately after injury. This patient also had painless movement of the hip three months after injury.

Case 39 died seven and one-half months after injury of a so-called heart attack. Because of infirmity, this patient was kept in bed and in a wheel chair, never becoming ambulatory on crutches. She was without pain during the last three months of life. Although roentgenograms made six months after injury showed no evidence of bone union, no change in position of the fragments had occurred. The treatment was considered adequate for the demands of this feeble patient, although solid union of the fracture did not take place. This case must certainly be classified as delayed union. There was no loss of position or of eburnation at the site of fracture six months after injury to indicate definite non-union.

Case 40 was a very feeble man who could not be taught to use crutches. Eight weeks after injury, his roentgenogram showed good position and no increased radiability at the site of the impacted fracture. He had free motion in his affected hip, without pain. He died from senility six months after injury.

Four of the fifty fractures became disimpacted, with displacement of the fragments, which necessitated reduction and fixation with a Smith-Petersen nail. All of these fractures united in good position (Fig. 6). In the original roentgenograms made immediately after injury all of these fractures appeared, in the anteroposterior view, to be impacted in valgus position, and, in the lateral view, with good alignment and impaction of the fragments. All of the separations or disimpactions occurred within the first ten days after injury: three while the patients were in bed and one when the patient caught her crutch on a rug and fell. In the last patient the original roentgenogram had shown slight separation of the fragments at the inferior margin of the neck (Fig. 7).

A careful review of the roentgenograms of the fractures that became disimpacted while the patient was in bed failed to reveal any feature that distinguished them from the twenty-three other impacted fractures, which healed without fixation and which were classified in Pauwels' Type II group. Roentgenograms of Case 44 illustrate the apparently good position of an impacted fracture which subsequently altered position (Figs. 8-A and 8-B).

When the fifty fractures were classified according to Pauwels' three groups it was found that:

FIG. 6

Case 44. Anteroposterior and lateral (external rotation) roentgenograms of the fracture after it was disimpacted, reduced, and nailed.

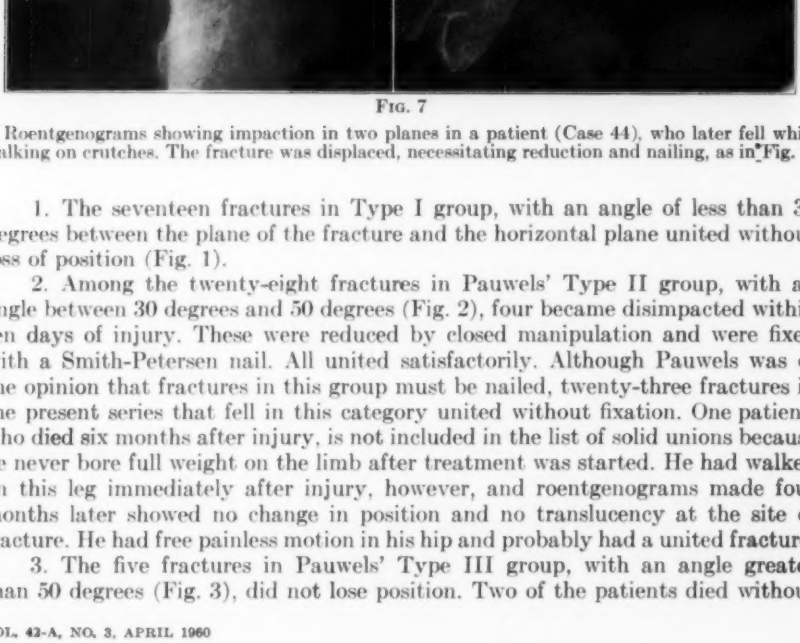

FIG. 7

Roentgenograms showing impaction in two planes in a patient (Case 44), who later fell while walking on crutches. The fracture was displaced, necessitating reduction and nailing, as in Fig. 6.

1. The seventeen fractures in Type I group, with an angle of less than 30 degrees between the plane of the fracture and the horizontal plane united without loss of position (Fig. 1).

2. Among the twenty-eight fractures in Pauwels' Type II group, with an angle between 30 degrees and 50 degrees (Fig. 2), four became disimpacted within ten days of injury. These were reduced by closed manipulation and were fixed with a Smith-Petersen nail. All united satisfactorily. Although Pauwels was of the opinion that fractures in this group must be nailed, twenty-three fractures in the present series that fell in this category united without fixation. One patient, who died six months after injury, is not included in the list of solid unions because he never bore full weight on the limb after treatment was started. He had walked on this leg immediately after injury, however, and roentgenograms made four months later showed no change in position and no translucency at the site of fracture. He had free painless motion in his hip and probably had a united fracture.

3. The five fractures in Pauwels' Type III group, with an angle greater than 50 degrees (Fig. 3), did not lose position. Two of the patients died without

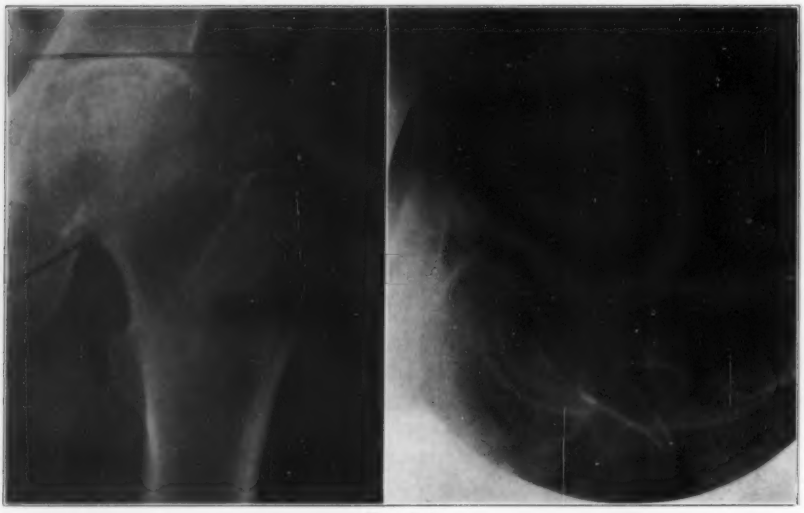

FIG. 8-A

Roentgenograms showing a fracture apparently impacted, in good position.

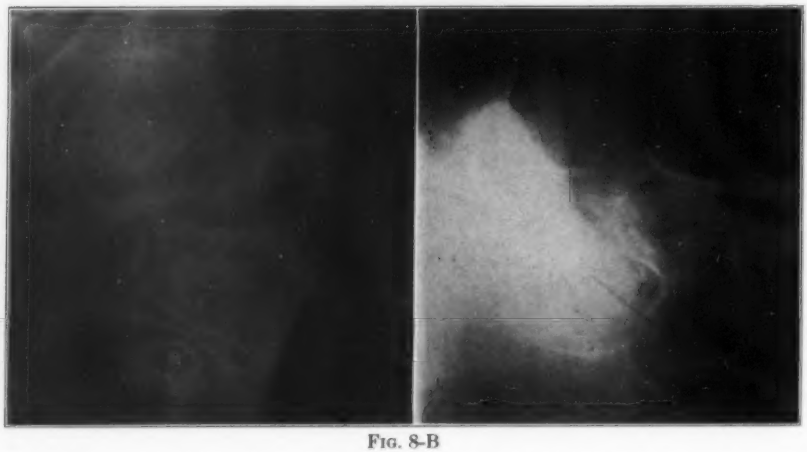

FIG. 8-B

The fracture separated, producing shortening and external rotation. This occurred nine days after the original injury, while the patient was in bed.

bearing full weight on the fractured limb, but roentgenograms made eight weeks and three months, respectively, after the fractures occurred demonstrated maintenance of position. The other three fractures in this group united in good position and with good function.

Avascular Necrosis

There were three cases of definite avascular necrosis in this series. This complication was recognized forty-eight months and thirty-two months, respectively, after fracture in two patients who had had rheumatoid arthritis. In the third patient the avascular necrosis developed thirty months after an intertrochanteric fracture, which occurred three years after the impacted fracture and was treated by open reduction and fixation with a nail and plate.

Aufranc, in a personal communication, suggested that if the femoral head is

in marked valgus in an impacted fracture, and the trabeculae in the central portion of the head are rotated past the vertical plane, this circumstance may impair revascularization and thus predispose to necrosis. In the three patients in this series in whom necrosis developed, the fractures were impacted in this extreme valgus position. Four other patients with similar amounts of valgus displacement have been followed for at least five years and in none has avascular necrosis developed so far.

These fifty cases have been followed for a minimum of five months and a maximum of fifteen years with a mean follow-up of three and one-half years. Obviously, one cannot draw too many accurate conclusions regarding the incidence of aseptic necrosis from this series. It would appear, however, that:

1. Aseptic necrosis is due to injury to the circulation of the femoral head at the time of fracture, rather than to the nailing procedure.

2. There is probably some merit in Dr. Aufranc's observation that aseptic necrosis is most apt to develop in hips that are impacted in marked valgus position.

3. In none of our patients in whom aseptic necrosis developed were there symptoms severe enough to warrant further surgery (they were discovered on routine follow-up). We know of at least four patients with marked valgus deformity in whom aseptic necrosis did not develop in from five to fifteen years' follow-up. It would therefore seem that one is not justified in breaking up the impaction, changing the position, and nailing such hips, with the hope that there would be less future trouble as a result of such meddling. It should be remembered that the only two bad results of impacted fractures reported by Linton were those that were disimpacted by a nailing procedure[3].

SUMMARY

The results in this series of impacted fractures of the femoral neck indicate that, with careful evaluation of each patient, excellent results can be obtained without operation and without prolonged hospitalization in a high percentage of these fractures. This regimen is not one to be advocated unless the patients can be followed with extreme care. A few of these impacted fractures will disimpact, requiring reduction and nailing.

This series indicates that Pauwels' rule regarding the cases in his Type I group is valid. There are apparently many exceptions to his statements regarding those fractures in the Type II and III groups.

REFERENCES

1. Aufranc, O. E.: Personal communication.
2. Crawford, H. B.; Merrill, E. F.; and Bridgman, C. F.: Radiography of the Hip Joint. Part Three: Radiographic Procedures during Hip-Joint Operations. Med. Radiogr. Photogr., **26**: 106–117, 1950.
3. Key, J. A., and Conwell, H. E.: The Management of Fractures, Dislocations and Sprains. Ed. 6. St. Louis, The C. V. Mosby Co., 1956.
4. Linton, Per: On Different Types of Intracapsular Fractures of the Femoral Neck. Surgical Investigation of Origin, Treatment, Prognosis and Complications in 365 Cases. Acta Chir. Scandinavica, Supplementum 86, 1944.
5. Linton, Per: Types of Displacement in Fractures of the Femoral Neck and Observations on Impaction of Fractures. J. Bone and Joint Surg., **31-B**: 184–189, May 1949.
6. Pauwels, F.: Cited by Watson-Jones.[7]
7. Watson-Jones, Reginald: Fractures and Joint Injuries. Ed. 3. Vol. 2, p. 630. Baltimore, The Williams and Wilkins Co., 1943.
8. Whitman, Royal: The Abduction Treatment of Fracture of the Neck of the Femur. An Account of the Evaluation of a Method Adequate to Apply Surgical Principles and Therefore the Exponent of Radical Reform of Conventional Teaching and Practice. Ann. Surg., **81**: 374–391, 1925.

Giant-Cell Tumor of the Cervical Spine

A Case Report

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A review of the literature reveals that the incidence of giant-cell tumor of the cervical vertebrae is rare. Because of the work of Jaffe [7,9], Lichtenstein [9,10], Besse and associates, and others, most authorities agree that so-called giant-cell tumors involving the vertebral column, especially above the sacrum, are aneurysmal bone cysts until proved otherwise. Difficulties arise among pathologists in differentiating giant-cell tumor from aneurysmal bone cyst in the vertebral column, where the former is rarely and the latter infrequently found. Most of the difficulties stem from old teachings in which aneurysmal bone cysts were included under giant-cell tumors [10]. Coley called aneurysmal bone cyst "atypical (subperiosteal) giant-cell tumor". Geschickter and Copeland named it "subperiosteal giant-cell tumor" and Ewing, "aneurysmal giant-cell tumor". Because of this early classification under "giant-cell tumors", it has required a great deal of writing and teaching since 1942 to identify aneurysmal bone cysts separately. Both tumors contain giant cells, which may cause confusion. However, according to Lichtenstein [10] and Besse and associates this should give no trouble in diagnosis, as will be pointed out later. A further source of difficulty stems from the relative inaccessibility of the tumor when it involves the vertebral column. Frequently, pathologists are called on to make the diagnosis from a scanty specimen that may not be representative of the entire lesion.

Lichtenstein [10] maintained that the histological distinction should be easy for one familiar with the two conditions. The presence of the cavernous vascular spaces, which is essential to establish the diagnosis of aneurysmal bone cyst, is lacking in giant-cell tumor. In the microscopic fields which are diagnostic of giant-cell tumor, the giant cells lie among stromal cells which have practically no intercellular substance. Ordinarily, the zones of solid tissue in an aneurysmal bone cyst, which contain the multinucleated cells, are fibrous or contain osteoid —findings not characteristic of giant-cell tumor. The giant cells in aneurysmal bone cyst tend to be rather small and have comparatively small nuclei, quite unlike giant cells of stromal origin in giant-cell tumor.

Ninety per cent of the giant-cell tumors are found in patients past the second decade of life, whereas 75 per cent of patients with aneurysmal bone cysts are under twenty years of age. Aneurysmal bone cysts are usually characterized on the roentgenogram by a ballooned-out area with the cortex largely, if not completely, destroyed. Giant-cell tumors usually involve the ends of long bones in the region of the epiphysis, whereas aneurysmal bone cysts when they occur in the long bones tend to be in the shaft. When an aneurysmal bone cyst is explored and the surgeon unroofs its thin, expanded dome, he is confronted by blood welling up, but not spurting, into the field, making thorough curettement difficult. The curettements are usually tissue fragments, which are soft or slightly gritty, yellow or reddish, and freely admixed with blood. In contrast to this, the specimen from a giant-cell tumor is more apt to be friable gray material. Lichtenstein [10] believed that the aneurysmal bone cyst is entirely benign and does not represent a neoplasm. He also stated it is due to some local vascular disturbance leading to increased venous pressure.

Jaffe [7] stated that the treatment for an aneurysmal bone cyst should be thorough curettage of the cyst wall and packing of the cavity with autogenous-

bone chips. This procedure is usually not feasible in the vertebral column where partial removal and spine fusion are preferable, but spine fusion may have to be postponed because of bleeding. Fortunately, even incomplete curettage of the cystic area is usually followed by healing. Roentgen therapy can be used if recurrence or extension occur. In other words, the prognosis for "cure" is much better for an aneurysmal bone cyst than for a giant-cell tumor, and it is therefore important to establish an accurate diagnosis.

The tumor described in the following case report appears to fulfill most of the criteria of a giant-cell tumor. Hence, this case is thought to be sufficiently unusual to warrant reporting.

A. P., a housewife, twenty years old, was first seen by me on May 17, 1955, after she had moved from Kentucky to Utah. She said she had been entirely well until November 1954, when she noted a sudden catch in her neck as she was jitterbugging. She first felt only a mild amount of pain, but the pain and stiffness had gradually increased. A chiropractic manipulation gave no relief, and pain and stiffness continued. In March 1955, while shaking out some wet clothes, she had a sudden, sharp, severe pain in her neck, followed by complete stiffness and continuous severe pain. Roentgenograms made at that time, in Kentucky, revealed an osteolytic lesion of the body of the third cervical vertebra, with posterior subluxation of the posterior elements of the third cervical vertebra and the second cervical vertebra with reference to the fourth cervical segment. She was hospitalized and placed in head-halter traction for two weeks, after which a cervical plaster-of-Paris cast was applied. The pain gradually subsided so that by the end of two weeks she had little or no pain. Her history was otherwise non-contributory.

On May 31, 1955, she was admitted to the Latter-Day Saints Hospital in Salt Lake City, where the cervical cast was removed. The patient was small (105 pounds) but well developed and well nourished. Motions of the cervical spine were moderately limited, as one would expect after approximately six weeks of immobilization. Palpation revealed mild tenderness over the upper cervical spine and moderate muscle spasm, but no evidence of swelling. Motions in the joints of both upper extremities were painless and of normal range. There was no muscle atrophy and all deep tendon reflexes were equal and active. The grip was normal bilaterally. No sensory changes were detected.

Roentgenographic examination revealed almost complete absence of the body of the third cervical vertebra with the antero-inferior angle of the body of the second cervical vertebra nearly touching the superior surface of the fourth cervical vertebra. The postero-inferior angle of the body of the second cervical vertebra was displaced posteriorly for a distance of at least one half an inch (Fig. 1).

At surgery on June 3, 1955, after prior insertion of Crutchfield tongs for controlled traction, the right third cervical pedicle was identified through a posterior approach and the location corroborated by roentgenogram. (The posterior approach was chosen because the anterior approach had not yet been popularized.) The pedicle was then carefully drilled, and a biopsy specimen obtained with a curette. This was not so difficult as it might appear because the tumor involved the pedicle as well as the vertebral body. Immediate frozen section indicated that the lesion was probably a giant-cell tumor. Complete excision of the tumor was obviously impossible. Accordingly, arthrodesis was performed from the second through the fourth cervical vertebrae, using bone from the patient's right posterior ilium. The bone for the graft had been removed prior to making the cervical incision to prevent possible transplantation of the suspected giant-cell tumor to the ilium[9].

The patient's convalescence was uneventful. Skeletal traction was continued for one week and then a cervical cast was applied. The patient was permitted to walk the next day and was discharged from the hospital on June 11, 1955, pain-free and with no evidence of cord or nerve-root compression.

The report * of the histological examination of the specimen was as follows: "Microscopic sections of tissue, including fragments of bone are seen. The stroma is composed of rather closely packed groups of fibroblastic type cells that are fairly plump in some instances but exhibit a few mitotic figures. Round cells infiltrate this mildly vascular stroma. Seen at rather regular intervals are large, prominent, multinucleated giant cells that may contain as many as fifty individual nuclei. No significant alteration of bone fragments is seen, except that there is minimal new bone formation. Areas of hemorrhage and degeneration are seen within the giant cell tumor focally. Hemosiderin is prominent within some of the phagocytic cells" (Fig. 3).

These slides were reviewed by Dr. Sherman S. Coleman and Dr. Clinton Compere; it was their conclusion that the lesion should be classified as a giant-cell tumor without malignant variation. If one were to grade the tumor according to Lichtenstein[11], it would fall into Group I. The sections were also reviewed by other widely known authorities. All agreed that this

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was a giant-cell tumor. Jaffe, in a personal communication, wrote: "I concur in the opinion that the lesion is a giant-cell tumor" and requested a copy of the preoperative roentgenograms for his file[6]. Dahlin noted that in his experience of well over 100 giant-cell tumors, only two had affected vertebrae above the sacrum[4]

FIG. 1

FIG. 2-A

Fig. 1: Lateral roentgenogram of the cervical spine, made on May 17, 1955. There is almost complete absence of the third cervical vertebra, close approximation of the second and fourth cervical vertebrae, and relative displacement of the second cervical vertebra.

Figs. 2-A, 2-B, and 2-C: Roentgenograms of the cervical spine, made four and one-half years after operation.

Fig. 2-A: Anteroposterior view, made through the open mouth.

FIG. 2-B
Lateral view, in flexion.

FIG. 2-C
Lateral view, in hyperextension.

After discharge from the hospital the patient was followed at frequent intervals in the office. Beginning two weeks after operation, she received through ports cut in the cast a total of 1,200 r to the third cervical vertebra. Treatment was given through a port five centimeters in diameter. The Maximar 250 was used at 150 kilovolts with a half-value layer of three millimeters of copper. Treatments extended over a period of sixteen days, during which time the patient experienced no discomfort.

Three months after operation the cast was removed. Roentgenograms showed solid bone fusion. The patient wore a cervical brace while ambulatory for the next six weeks, at which time it was discarded. She remained asymptomatic until approximately November 25, 1955, when she began having some mild cervical pain, with rotation of the neck to the left and with forward flexion. Examination at that time revealed moderate tenderness to palpation over the fusion area. There was no muscle spasm or swelling. The range of motion of the cervical spine was approximately 75 per cent of normal with mild pain on rotation to the left and with forward

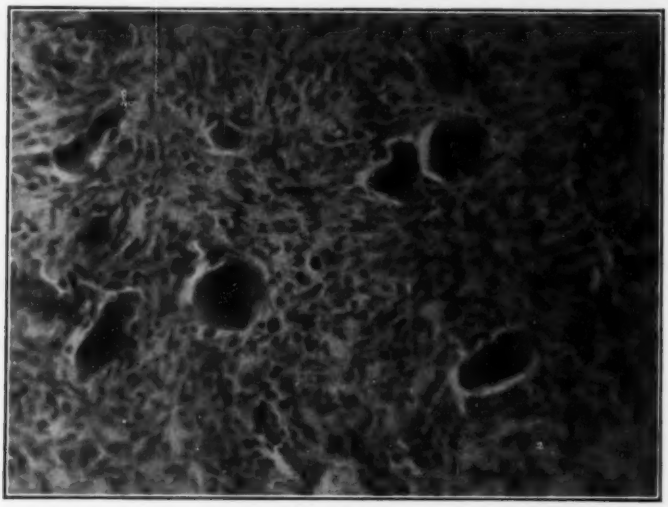

FIG. 3-A

Microscopic appearance of the tumor (× 150).

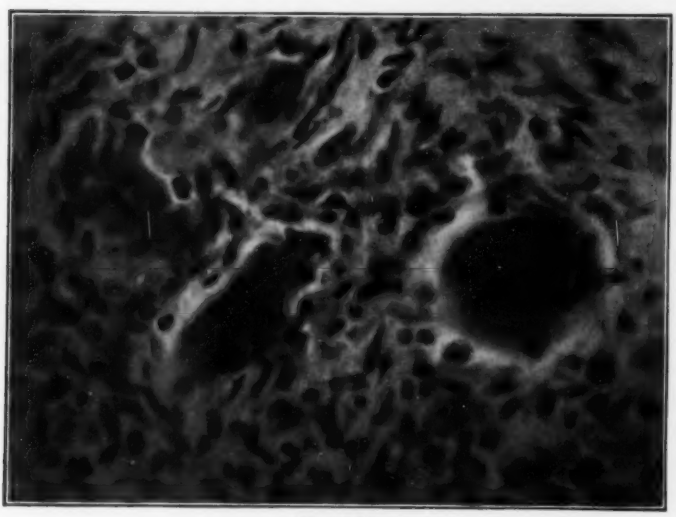

FIG. 3-B

Higher-power view (× 350).

flexion. Reflexes were equal and active bilaterally, and there were no sensory changes. The grip was normal. There was no atrophy. Because of the apparent increase in symptoms, additional radiotherapy amounting to a tumor dose of 1,000 r was administered. At this time, with no cast to interfere, therapy was given through right and left lateral ports and a posterior port. The Maximar 250 apparatus was used at 250 kilovolts and fifteen milliamperes. A Thoraeous No. 3 filter was used, which yields an x-ray beam with a half-value layer of three millimeters of copper. A port of seven square centimeters was used at fifty centimeters focal-spot skin distance.

Within approximately two months' time, the patient's symptoms completely subsided. Since that time she has been able to do her regular housework. She has been seen at approximately three-month intervals. She has had no pain whatsoever and her only complaint has been a tired feeling in her neck after an excessively hard day, such as during spring house cleaning. She was last seen on December 22, 1959, when she said she had given birth to a boy, weighing eight pounds and two ounces, in August 1958. She said that her pregnancy was uneventful and that she had no symptoms referable to her neck or upper extremities. When examined, the range of motion of the cervical spine was normal except for the loss of the last 10 degrees of right and left rotation and the last 10 degrees of forward flexion. There was no tenderness to palpation and no muscle spasm. Reflexes were equal and active bilaterally. There were no sensory changes. There was no atrophy, and muscle strength was normal.

The last roentgenographic examination, made on December 22, 1959, revealed further evidence of healing. Lateral bending views revealed solid arthrodesis from the second through the fourth cervical vertebrae (Figs. 2-A, 2-B, and 2-C).

SUMMARY

A case of giant-cell tumor involving the third cervical vertebra in a woman, twenty years old, has been presented. The treatment and the result after a four-year follow-up are reported for the purpose of recording one more case of this rare lesion—a proved giant-cell tumor of the vertebral column.

REFERENCES

1. Besse, B. E., Jr.; Dahlin, D. C.; Pugh, D. G.; and Ghormley, R. K.: Aneurysmal Bone Cysts: Additional Considerations. Clin. Orthop., 7: 93-102, 1956.
2. Boyd, Harold: Personal communication, 1949.
3. Coley, B. L.: Neoplasms of Bone and Related Conditions. Their Etiology, Pathogenesis, Diagnosis, and Treatment, p. 168. New York, Paul B. Hoeber, Inc., 1949.
4. Dahlin, D. C.: Personal communication, 1959.
5. Ewing, James: Neoplastic Diseases. A Treatise on Tumors. Ed. 4, pp. 323-324. Philadelphia, W. B. Saunders Co., 1940.
6. Geschickter, C. F., and Copeland, M. M.: Tumors of Bone. Ed. 3, p. 309. Philadelphia, J. B. Lippincott Co., 1936.
7. Jaffe, H. L.: Tumors and Tumorous Conditions of the Bones and Joints, pp. 60-61. Philadelphia, Lea and Febiger, 1958.
8. Jaffe, H. L.: Personal communication, 1959.
9. Jaffe, H. L., and Lichtenstein, Louis: Solitary Unicameral Bone Cyst, with Emphasis on the Roentgen Picture, the Pathologic Appearance and the Pathogenesis. Arch. Surg., 44: 1004-1025, 1942.
10. Lichtenstein, Louis: Aneurysmal Bone Cyst. A Pathological Entity Commonly Mistaken for Giant-Cell Tumor and Occasionally for Hemangioma and Osteogenic Sarcoma. Cancer, 3: 279-289, 1950.
11. Lichtenstein, Louis: Bone Tumors, pp. 107, 130-138. St. Louis, The C. V. Mosby Co., 1959.

The Cytodifferentiation of Osteoblasts in Tissue Culture

A Description of Cellular Emigrations from Embryo Chick-Leg Bones*†

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The objectives of the research on which this report is based were: (1) to provide an environment in which bone cells (osteoblasts) would continue to be maintained in their differentiated form and functioning capacity and also be amenable to continuous observation with phase-contrast and interference-contrast microscopy; and (2) to detect the effect on these cells of various biophysical and biochemical alterations of this environment. The data in this report are a partial fulfillment of these objectives and are presented as a document of the cytodifferentiation of osteoblasts in tissue cultures of embryonic chicks.

Since Fell [5] introduced the cultivation technique of fragments of leg endosteal bone of chick embryos, there have been several other reports [1,6,9,10,13,19] that have referred to the cultivation of osteoblastic cells in tissue cultures, but these have not included detailed photographic cytological documentations. Cultures of bone fragments in plasma-clot cultures have been shown to react positively to staining for alkaline phosphatase [13,19]. Preliminary studies in this laboratory indicated that among the abundant fibroblastoid outgrowths occurring with the cultivation of fragments of endosteal bone of embryonic chicks in plasma clots there were cells that selectively reacted positively to Gomori's staining technique to demonstrate alkaline phosphatase [11]; this was a dense reaction in both the cytoplasm and the nuclei. It was easy to observe these cells with the high-power and low-power objectives after fixation and staining, but to segregate them from the stromal cells in the living state was impossible. Furthermore, when the cultures were stained with Sudan IV, the alkaline-phosphatase-positive cells were generally seen to be free of fat, whereas most of the surrounding and overlying fibroblastoid cells showed dense fatty accumulations.

When similar bone explants were cultivated under strips of dialysis cellophane [26], which replaced the plasma clots, the proliferating cells emigrated in very flat cellular sheets. In this condition of cultivation two predominant cell types were observed in segregated zones. The data of this presentation were derived by using this technique, and demonstrate that osteoblasts of embryonic chicks may be microscopically defined in their living, unstained, and functioning forms and, as such, may be followed over a number of weeks in various experimental conditions. Even single living osteoblasts were observed in their differentiated form under maximum powers of phase-contrast and interference-contrast microscopy, and often these observations were combined with time-lapse motion-picture studies.

MATERIALS AND METHODS

Bone Explants

Embryonic chicks from a constant source and breed were incubated for

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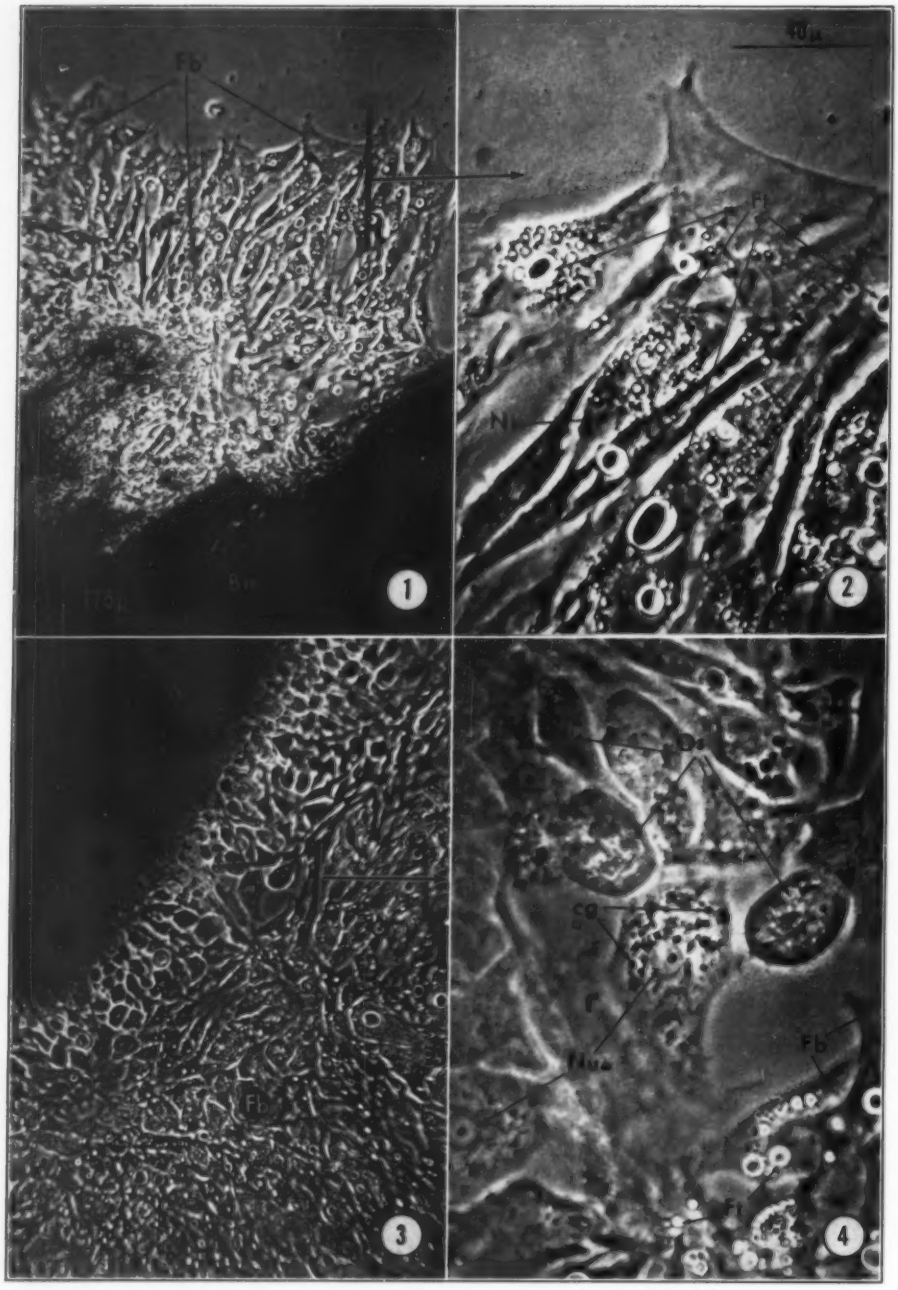

PLATE I

Figs. 1 and 2: These phase-contrast photographs are low-power and high-power views of fibroblastoid (*Fb*) outgrowths of a leg bone of a fourteen-day-old embryonic chick after four days of cultivation (Fig. 1, × 140; Fig. 2, × 625).

Figs. 3 and 4: These are low-power and high-power phase-contrast views of the secondary or osteoblastic emigration from a leg bone of a fourteen-day-old embryonic chick after two weeks of cultivation. They show the sharp differences in morphology between the osteoblastic zone (*Os*)

and the fibroblastic zone (*Fb*). The magnification lines in Figs. 1 and 2 may be correspondingly used for these figures. The fat droplets (*Ft*) of the fibroblastic cells and the dark cytoplasmic granules (*cg*) of the osteoblasts are shown. Cell *A* is also shown in Figs. 11 and 12 (Fig. 3, × 140; Fig. 4, × 625).

thirteen days. In all cases the mid-third of the shaft of the tibia was used according to the technique of Fell [5]. After the stripping off of the periosteum, the bone was longitudinally split with scalpels, the two halves similarly split, and the marrow scraped away. In so doing, usually eight fragments of endosteal bone about one by two millimeters were prepared from each leg. These fragments were washed three times in watch glasses with the standard nutrient prior to placing them in the chambers.

Standard Nutrient

The nutrient solution used throughout these experiments was composed of the following: (1) Medium No. 1066, 75 per cent (Connaught Medical Research Laboratories, Toronto); (2) calf serum, 20 per cent; and (3) whole-egg ultrafiltrate, 5 per cent (both from the Microbiological Associates, Bethesda). Medium No. 1066 is a chemically defined variant of Medium No. 858 [12], and the stability and uniformity of the whole-egg ultrafiltrate [4] have been established. Use of this mixture produced uniform results.

Cultivation Procedures

Multipurpose culture chambers [17,18,20,21,26,28,29] were used exclusively. Basically, these chambers are composed of two flat steel retaining plates which compress between them two coverslips separated by a flat rubber gasket through which a hypodermic needle may be inserted. Thus, each chamber consists of five flat pieces sandwiched together and held firmly by four Allen-head bolts. The two flat retaining plates have large central holes so that the major surfaces of each assembled culture chamber are the No. 1 glass coverslips.

Strips of cellophane [26] cut from Visking dialysis tubing were prepared by a brief alcohol rinse that was followed by three rinses in the standard nutrient. The fragments of endosteal bone were spread out on a coverslip surface, overlaid with a piece of the nutrient-moistened cellophane, and the chamber was closed by completion of the assembly procedure. Four fragments of bone were cultivated in the smaller (two-by-three-inch) chambers, and twenty fragments were cultivated in the larger (four-by-four-inch) chambers. Syringes of appropriate size (two or twenty milliliters) with needles (No. 25 or No. 20) full of the nutrient and an extra needle for an air vent were inserted through the lateral walls of the gaskets for the filling of the chambers. Upon completion of these procedures, the chambers were placed in an incubator with the temperature at 37 degrees centigrade during the cultivation period. Fluid exchanges were made semiweekly by reversing the nutrient-filling process.

Observations

Each explant was observed through a Bausch and Lomb phase-contrast microscope at least every third day during the cultivation period of twenty-two days. The phase-contrast microscope was fitted with a long-working-distance condenser, which is necessary for these chambers. Phase-contrast and interference-color-contrast records were made with a time-lapse sixteen-millimeter movie unit (Electro-Mechanical Development Co., Houston).

Cytochemistry

Cultures were fixed in cold formol (5 degrees centigrade for ten minutes) and stained for alkaline phosphatase by the calcium-cobalt method of Gomori [11] and after diastase digestion for the periodic acid-Schiff reaction of Hotchkiss [19] to

PLATE 2

PLATE 2

Figs. 5 and 6: Fig. 5 shows one end of an endosteal-bone fragment of a fourteen-day-old embryonic chick as observed by phase-contrast microscopy after two weeks of cultivation. Fig. 6 is the same portion of bone after formol fixation and staining for alkaline phosphatase by Gomori's technique. The osteoblastic zone, which is nearer the bone explant and composed of cells that are smaller and denser by phase contrast (Fig. 5), may be seen to be composed of the cells that stain deeply for alkaline phosphatase in Fig. 6. In the upper and lower portions of these illustrations are boxes that indicate the areas shown under higher magnification in Figs. 7 through 10 (× 140).

demonstrate mucopolysaccharides [14]. Other cultures, after formol fixation, were stained with Delafield's hematoxylin or Sudan IV (saturated solution in diethylene glycol monoethyl ether) or both.

RESULTS

After the first twenty-four hours of cultivation an occasional endosteal-bone fragment showed a varying number (one to twenty-five) of fusiform or kite-shape fibroblastoid cells. By three or four days, most of the explants contained a perimeter of these cells, which in some areas were abundantly aggregated. Figure 1 shows a typical early fibroblastoid (stromal type of cell) outgrowth, and Figure 2 represents a higher magnification from the same microscopic field. These figures illustrate the nearly universal occurrence of rather large cytoplasmic fat droplets associated with this cell type. In five to seven days a secondary emigration of cells was observed in most of the explants. The number of these latter cells increased to a peak value at about fifteen to eighteen days of cultivation, whereas the fibroblastoid cells underwent a continuous and rapidly spreading multiplication for six to eight weeks. This secondary emigration consisted of a type of cell that was relatively dense under the phase-contrast microscope and under low power appeared to be thicker and rounder than the fibroblastoid cells (Figs. 3 and 4). No evidence of an increase in the number of these secondary cells could be determined after three weeks, and by this time they were often densely intermeshed with the stroma. These cells were considered to be osteoblasts because the black cytoplasmic granules in many of them closely resembled the granules in the stained cells that showed a positive alkaline-phosphatase reaction. In Figure 4 the granular structure of the cytoplasm may be compared with the fat-containing cytoplasm of the fibroblastoid cells. The nuclei were round or oval and contained one or two small nucleoli. The cytoplasm of some osteoblasts was relatively clear, whereas in others it was full of the phase-contrast dark or light granulations.

A montage of one explant in the living state and after staining by Gomori's technique for the demonstration of alkaline phosphatase is shown in Figures 5 and 6. This represents the tip end of one of the fragments of endosteal long bone. The blocks at the top and the bottom of the figures indicate the portions of this preparation that are shown in the more magnified illustrations in Figures 7 through 10. In Figure 5, a fourteen-day outgrowth is shown, and the zone of osteoblasts is easily delineated from that of the more peripheral fibroblastoid cells. The identical area is shown again with brightfield illumination in Figure 6 after cold formol fixation and staining for alkaline phosphatase. The strong reaction in the proximal cells (osteoblasts) may be noted in both the cytoplasmic granules and the nuclei, but there is no reaction in the fibroblastoid zone. It is especially interesting to observe that cell *B* in Figure 7 is very full of phase-contrast dark cytoplasmic granules (*cg*) and also gave a quite dense alkaline-phosphatase staining reaction. However, cell *E*, which is comparably full of cytoplasmic granules, showed a weak alkaline-phosphatase reaction. Conversely, other cells, such as *F*, *G*, and *J*, have less granules than cell *E* but showed a stronger reaction for alkaline phosphatase. Other comparisons of cells are shown in Figures 9 and 10. The granules of these osteoblasts also were equivocally stained by the periodic acid-Schiff stain after diastase digestion but these preparations were not suitable for photographic documentation. With hematoxylin, similar

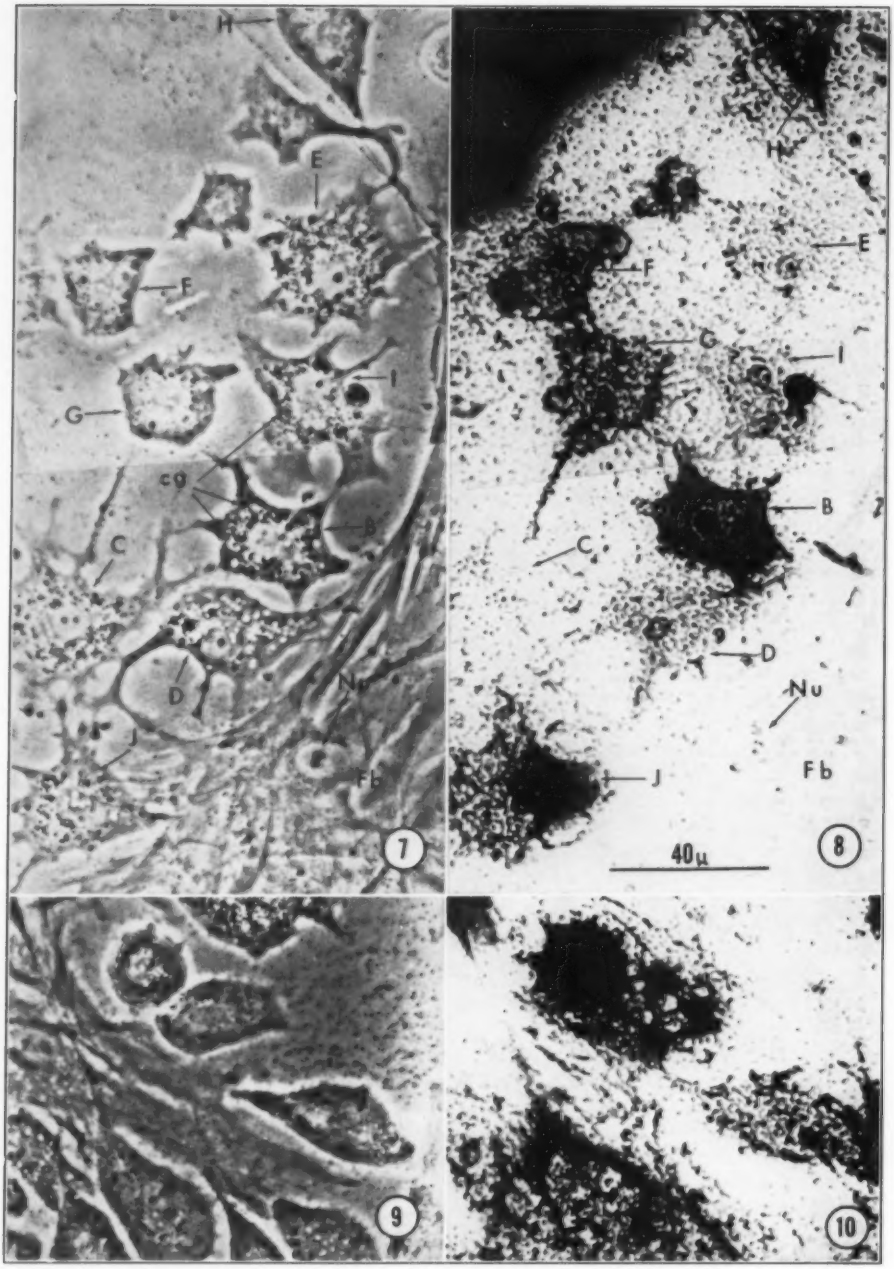

PLATE 3

Figs. 7 through 10: These are high-power views of the areas indicated in Figs. 5 and 6. They illustrate cytological features of specific cells observed with phase-contrast microscopy (unstained) and brightfield (alkaline-phosphatase stained) microscopy (× 625).

Figs. 7 and 9: These show the osteoblasts with varying amounts of cytoplasmic granules adjacent to elongated and non-fat-containing fibroblastoid cells (*Fb*).

Figs. 8 and 10: These show the alkaline-phosphatase reactions, and comparisons may be made between the labeled cells, *B*, *C*, *D*, *E*, *F*, *G*, *H*, *I*, and *J*. There is no alkaline-phosphatase reaction in the fibroblastic cells in the lower right portion of Fig. 8. The magnification line in Fig. 8 may be used for all of the illustrations.

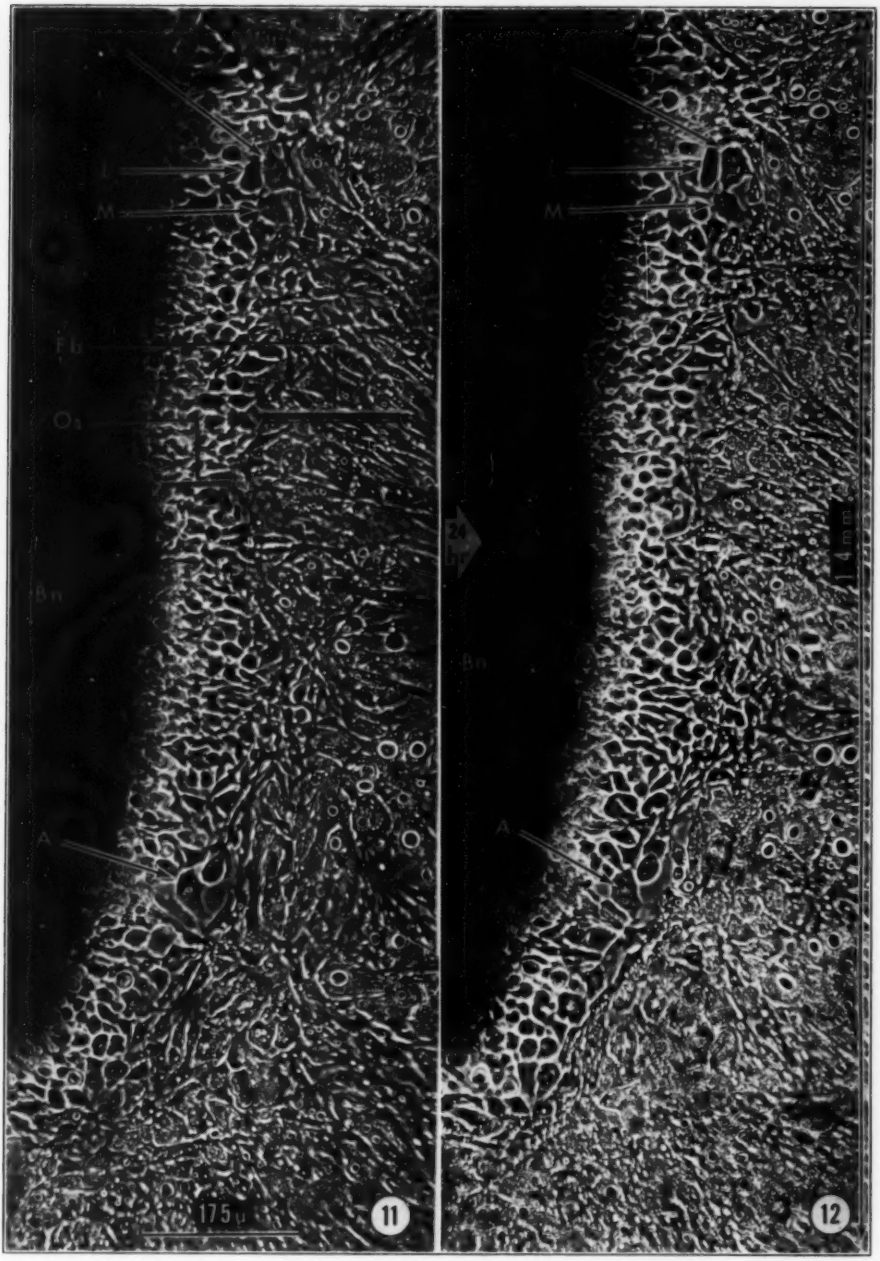

PLATE 4

Figs. 11 and 12: These represent phase-contrast views of the tip end of a bone fragment of a fourteen-day-old embryonic chick after fourteen and fifteen days of cultivation. The clear demarcation between the osteoblastic (*Os*) and the fibroblastic (*Fb*) zones, and the changes in specific cells (*A*, *K*, *L*, *M*) that have occurred during the twenty-four-hour interval may be observed. Also, an increase in size or number of the fibroblastoid cells (*Fb*) is apparent. Many of the fat droplets of Fig. 11 are larger in Fig. 12. Cells *K*, *L*, *M* of Fig. 12 are shown under higher power in Figs. 13 and 14 (× 140).

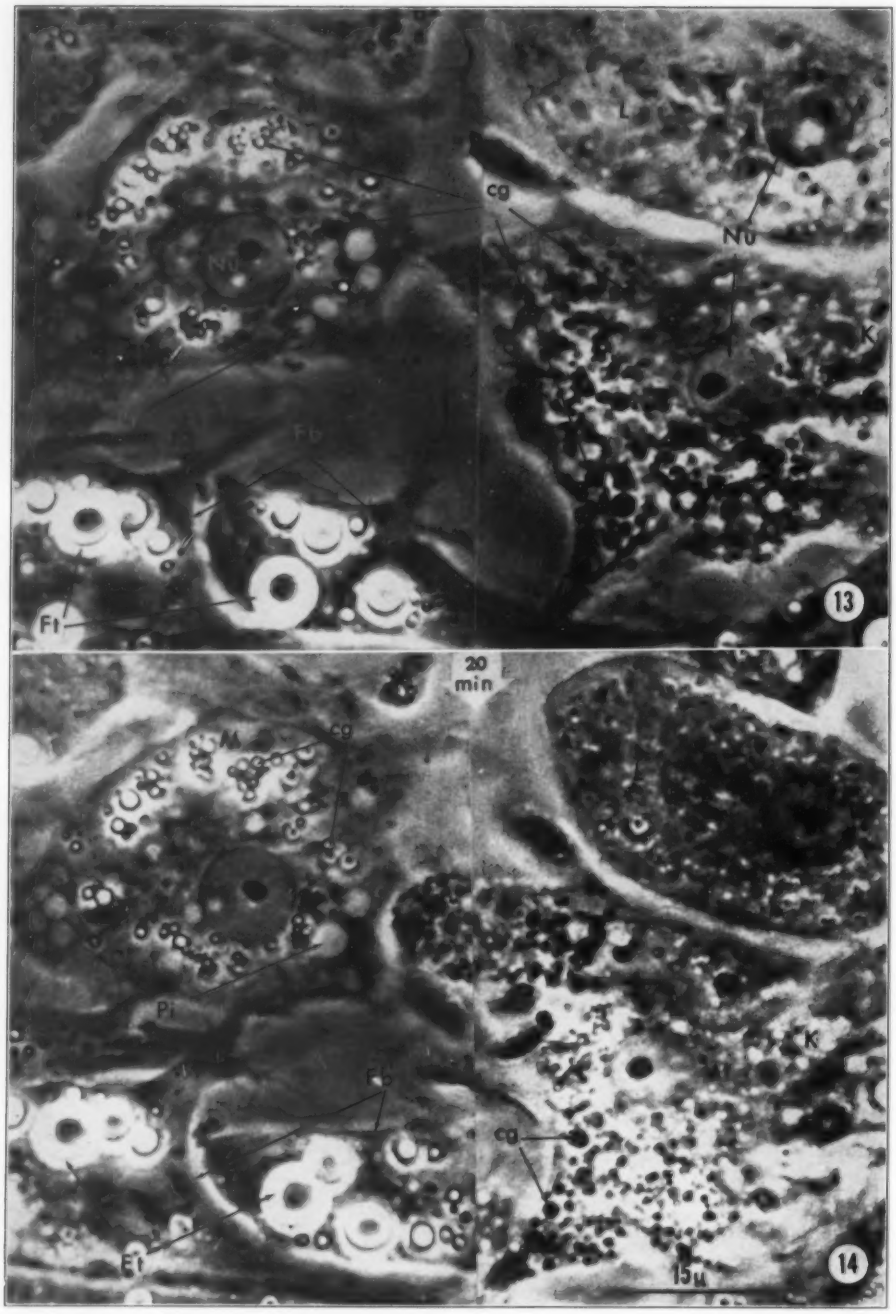

PLATE 5

Figs. 13 and 14: These are phase-contrast views of the osteoblasts *K*, *L*, and *M* of Fig. 12 and were taken at a twenty-minute interval. Cell *M* was undergoing vigorous pinocytosis, *Pi*, (cell-drinking), cell *K* apparently had ceased this activity after a heavy engorgement of fluid droplets, and cell *L* appears to have been in a state of quiet peripheral cell activity (membrane smooth with no extensions or ruffles). The usually dark cytoplasmic granules (*cg*) appear to be bright in certain areas of cell *M* as they were not in perfect focus. In Fig. 12 it can be observed that these granules were actually phase-contrast black (× 1650).

cells were very deeply stained compared with the adjacent fibroblastoid cells. The fat droplets (*Fb*) of the fibroblastoid cells showed pronounced staining with Sudan IV, but the osteoblasts (*Os*) were generally unreactive with this stain.

One explant that was cultivated for fourteen days is shown in Figure 11 and again twenty-four hours later in Figure 12. These figures point out the relatively sluggish motion of the osteoblasts close to the bone fragment. This may be observed by specifically comparing cells *A*, *L*, *M*, and *K* in the two photographs.

Cells *K*, *L*, and *M* in Figure 12 are reproduced again by high-power objectives in Figures 13 and 14. These two illustrations were photographed twenty minutes apart and show active pinocytosis (cell-drinking) in *M*. The varying amounts of cytoplasmic granulations in the different osteoblasts are also indicated, but the conditions that provoked such variations were not fully determined, although there was a suggestion of a relationship to pinocytosis.

Occasionally, osteoblasts were observed to be arranged as nests of cells surrounded by the stroma (Figs. 15 through 18). Most of the cells in Figure 15 had very few cytoplasmic granules (*cg*). The surrounding fibroblastoid cells were sharply segregated from the osteoblasts by a clear space and by their morphologically distinct appearance. The nests of osteoblasts so formed were composed of as few as one cell (*T*) or as many as the approximately forty cells grouped in the semilunar form shown in Figure 15. The pleomorphism of these cells is further illustrated in Figure 16. Figures 17 and 18 are high-power pictures of two of the osteoblasts contained in the semilunar nest shown in Figure 15. These cells show varying amounts of filamentous mitochondria and microkinetospheres [22]. Cell *R* with two nuclei, and cell *S*, with a very eccentric nucleus, each clearly shows a round and centrally located Golgi complex (*Go*).

Another nest that was closer to the explant is shown in Figures 19 and 20. Some of these cells contained dense accumulations of the presumably alkaline-phosphatase-positive granules in the cytoplasm. In Figures 21 and 22 the various cytoplasmic structures of three of these cells (*X*, *Y*, and *Z*) are shown under high magnification. At the periphery of cell *Y*, extended processes overlap and intermesh with the adjoining cells. Some of these processes contain mitochondria and the tiny ovoidal microkinetospheres. When these cytoplasmic organoids are located in these processes, they are potentially available for an interchange with the cytoplasmic organoids of neighboring cells [25].

DISCUSSION

For many years, the primary objectives of tissue culture were the development of (1) methods which were suitable for cell cultivation in a visible environment apart from the animal of origin, and (2) methods by which such cellular outgrowths could be maintained over an extended length of time. Both of these objectives have nearly been achieved. Of equal importance, but less successful, has been the development of techniques which would be conducive to outgrowths of differentiated cells. Some time ago, tissue culturists [2,3,7,8] were interested in stimulating cells in such a manner that they would become malignant, but in more recent years it has become fairly obvious that cells that remain in tissue culture for some time become malignant regardless of how they are treated [16,27].

For tissue culture to be used as a means of ascertaining physiological activities of tissues and organs, it is obviously necessary to have representative cells in an environment in which they will not dedifferentiate to malignant forms. This study has shown a technique by which cells from bone fragments of fourteen-day-old embryonic chicks emigrated in their differentiated form after five to seven days of cultivation into a field that was readily observed with phase-contrast or interference-contrast microscopes. This technique, in which strips of dialysis cellophane were used to anchor the bone fragments, in place of plasma clots, produced a very compressed field for these cellular patterns.

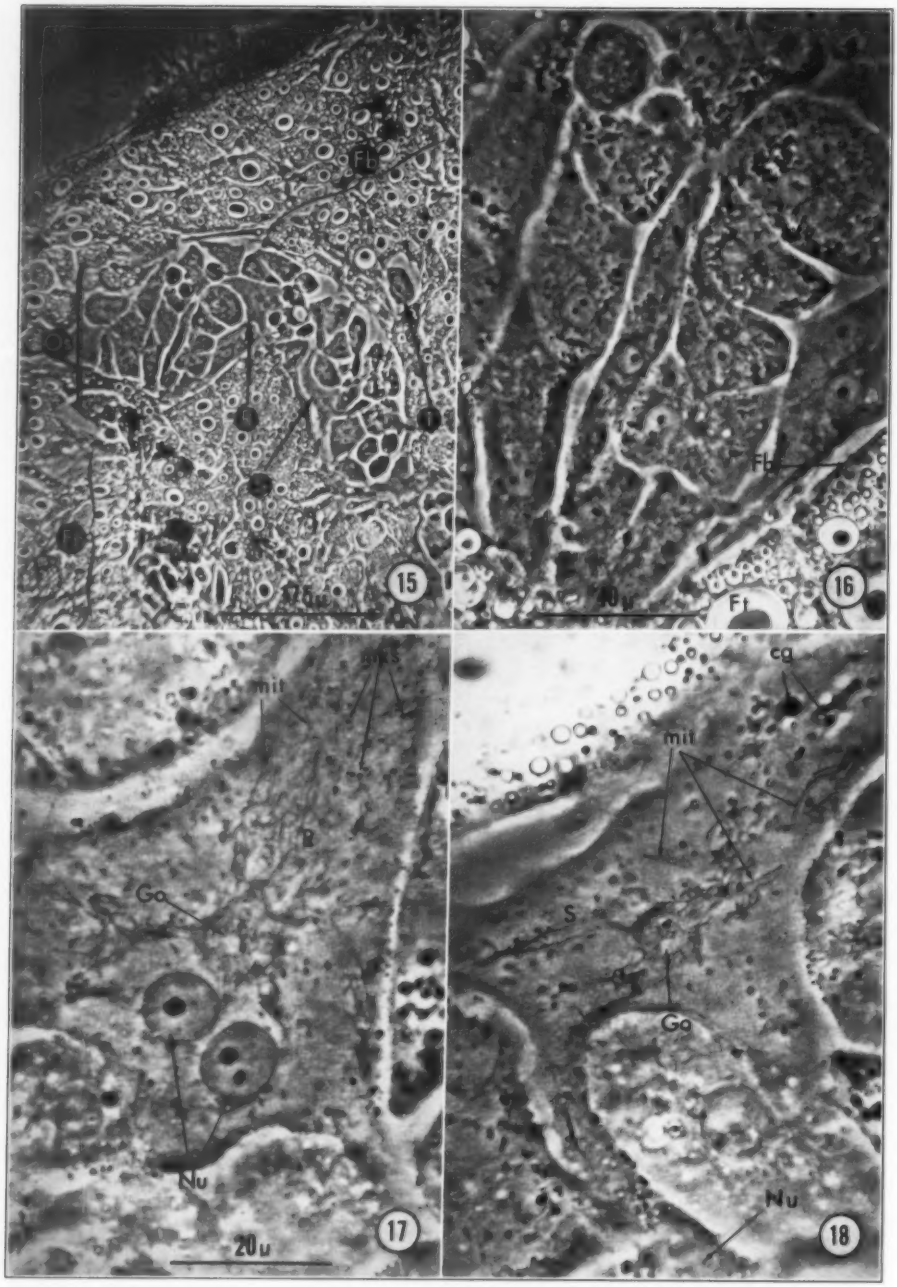

PLATE 6

Figs. 15 to 18: These represent phase-contrast pictures of osteoblasts and fibroblastoid cells that emigrated from a fragment of endosteal leg bone of a fourteen-day-old embryonic chick after two weeks of cultivation.

Fig. 15: This is a low-power view of an osteoblast nest that was surrounded by fibroblastoid cells. Many of these bone cells contain relatively few phase-contrast black cytoplasmic granules, and their shapes are quite variable. Occasionally, even one osteoblast (cell *T*) may be isolated by

a surrounding ring of fibroblastoid cells. There was a uniform fatty accumulation in the stromal cells (× 140).

Fig. 16: This is a segment of the left-hand portion of the semilunar osteoblastic nest shown in Fig. 15 under high power (× 625).

Fig. 17: This is a portion of cell *R* that was located in the center of the nest in Fig. 15. This cell was quite devoid of the larger black cytoplasmic granulations. The mitochondria (*mit*) and ovoidal microkinetospheres (*mks*) were scattered throughout the cytoplasm, and the Golgi complex (*Go*) was located in the center of the cell (× 1250).

Fig. 18: This shows cell *S* of the lower-right-hand portion of the osteoblastic nest in Fig. 15. This cell has essentially the same features of cell *R*, although it was peculiarly shaped so that the nucleus (*Nu*) had a very eccentric location in the tip of a long, curved, finger-like projection at the bottom of the illustration. The Golgi complex, however, was centrally located, as in cell *R* (× 1250).

Emigrations were observed in two sharply defined zones of cell types: (1) fibroblastoid cells, and (2) osteoblasts. The fibroblastoid cells were characterized by (1) being flatter and broader than the osteoblasts; (2) having variegated shapes, generally fusiform or kite-shape; (3) having large cytoplasmic fat accumulations; (4) multiplying rapidly; and (5) generally being non-reactive to staining for alkaline phosphatase. On a few occasions, however, the fibroblastoid cells, which were close to the explants and were dividing rapidly, showed a fine cytoplasmic reaction to staining for alkaline phosphatase and a denser reaction in the nuclei.

The osteoblasts were observed in the zone immediately surrounding the bone and apparently were limited from extensive migrations by the fibroblastoid stroma that had developed earlier. These bone cells were characterized by (1) being smaller and thicker than the fibroblastoid cells; (2) having variegated shapes; (3) staining densely with hematoxylin; (4) containing large cytoplasmic granules that in many cells stained positively for alkaline phosphatase and (after diastase digestion) positively for the periodic acid-Schiff reaction; (5) containing a more definite nucleus that generally stained positively for alkaline phosphatase; (6) showing a dense alkaline-phosphatase reaction in the nucleoli; (7) occasionally undergoing pinocytosis; and (8) rarely being observed in mitosis. Transitional forms between the two zones were observed and were characterized by cells with a decreased amount of the dark cytoplasmic granules and a few cytoplasmic fat droplets. Since the explants for these cultures were prepared from endosteal bone according to Fell's [5] technique (the periosteum was stripped from the bone, and the marrow was removed) it is apparent that the cells which emigrated in the form described were truly osteoblasts. Such a fragment would not contain other cells with these osteoblastic characteristics [15].

It was shown (Figs. 7 through 10) that cytoplasmic granules of the osteoblasts did not always have the dense stain of an alkaline-phosphatase reaction. Because of the many phase-clear droplets in some osteoblasts and their similarity to cells of other tissues more vigorously studied [22,23], it was reasonable to postulate for the moment that the cytoplasmic granules of the osteoblasts were also droplets of pinocytosis (cell-drinking) activity that had had their phase display reversed (white to black). Other cells possessed very few, if any, cytoplasmic granules and probably had not undergone any major pinocytosis for some interval of time (three to six hours) before they were photographed. Since the cytoplasmic microkinetospheres have been linked to structures of other cells that have been proved to be highly enzymatic [22], and since in the osteoblasts they showed a dense alkaline-phosphatase reaction, they were quite likely the key source of the staining variations. Observations of strain HeLa cells in which there is an abundance of acid phosphatase in the microkinetospheres have shown that the microkinetosphere aggregates may or may not share this enzyme at the moment of staining with the fluid droplets of pinocytosis to which they have become attached [22]. It is, therefore, quite possible, although only conjecture, that the alkaline-phosphatase reaction in the osteoblasts observed was in some way a similar expression of enzyme distribution between microkinetospheres and pinocytosed droplets.

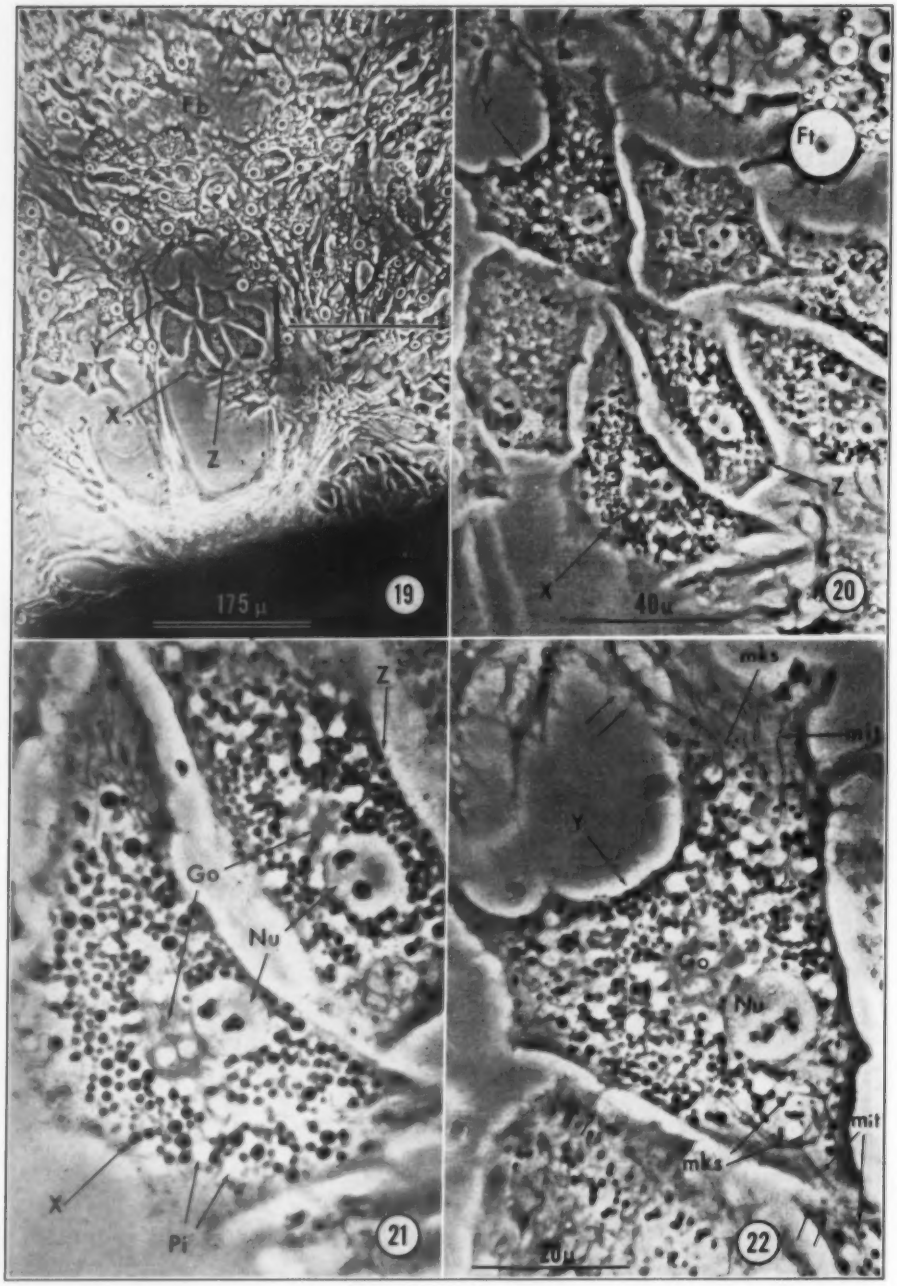

PLATE 7

Fig. 19: This is a phase-contrast view of another nest of osteoblasts cultivated from a leg bone of a fourteen-day-old embryonic chick for two weeks. The nest was much closer to the bone explant than that in Fig. 15 (× 140).

Fig. 20: This is a higher magnification of the osteoblast nest of Fig. 19 and shows the wide variation in the number of cytoplasmic granulations in the different cells (× 625).

Fig. 21: This shows cells *X* and *Z* of the nest of Fig. 19. The clear Golgi complex (*Go*) was typically located in the center of the cells and adjacent to the nuclei. Also shown are the dense

cytoplasmic granulations, mitochondria (*mit*), microkinetospheres (*mks*), and the clear pinocytosed droplets (*Pi*) (× 1250).

Fig. 22: Cell *Y* contains features similar to those shown in cells *X* and *Z* of Fig. 21. In addition, there are three points indicated by double arrows at the top and the bottom of *Y*, which indicate areas of cellular bridging or overlap. It is possible that at these points cytoplasmic organoids may penetrate cell membranes and be transferred to neighboring cells (× 1250).

KEY: *Bn* = endosteal-bone explant; *Fb* = fibroblastoid cell(s); *Ft* = fat droplet; *Nu* = nucleus; *A, B, C, D, E, F, G, H, I, J, K, L, M, R, S, T, X, Y, Z* = specific osteoblasts; *Os* = osteoblast(s); *cg* = cytoplasmic granules often associated with alkaline phosphatase; *Pi* = pinocytic droplets; *mit* = mitochondria; *mks* = microkinetospheres; *Go* = Golgi complex.

Only after staining for alkaline phosphatase was it ascertained that osteoblasts emigrated from endosteal-bone fragments cultivated in plasma clots. This suggests that the cellophane-strip technique may permit observations of the osteoblasts in their unstained and living form only because it provides a physical segregation of cell types imposed by the very thin cultivation space available between the cellophane and the coverslips. If this were true, the most vigorously dividing and rapidly emigrating cells, the fibroblasts, would project out long processes and establish a field of cells before the slower and less mobile osteoblasts had moved into the area adjacent to the bone. This is a satisfactory explanation for bone-differentiated outgrowths, but work with other tissues carried out in this laboratory now suggests that the dialysis effect of closely applied cellophane is a major factor of differentiated outgrowths. For instance, cultures of embryonic muscle have never appeared in a differentiated form with plasma-clot techniques in the multipurpose culture chambers. With the dialysis membranes, however, long straps of contracting and cross-striated muscles have emigrated with great regularity [24]. Secondly, cultures of embryonic lungs have not only produced epithelial sheets, as in plasma-clot cultures, but with dialysis strips the epithelia have further differentiated into aveolar-like buds. Many of these buds have had perimeters of pseudostratified epithelium, and often coursing between these areas have been elongated and non-striated lazily contracting cells. These, perforce, must be differentiated smooth-muscle cells. Other embryonic tissues have been similarly investigated in both plasma-clot and cellophane-strip cultures, and the greater cell differentiation with the latter type of culture technique has been most apparent. These supportive data indicate that the osteoblasts in the cultures described in this report probably have been favored by the mechanical segregation as well as by some other property of the cellophane, such as its function as a semipermeable membrane. The dialysis resulting from this property might favor retention of local cellular products that otherwise would be washed away with fluid exchangings.

REFERENCES

1. CHEVREMONT, M.. *In* Wound Healing and Tissue Repair, p. 21. Edited by W. B. Patterson. Chicago, The University of Chicago Press, 1959.
2. EARLE, W. R.: Production of Malignancy *in Vitro*. IV. The Mouse Fibroblast Cultures and Changes Seen in the Living Cells. J. Nat. Cancer Inst., **4**: 165–212, 1943.
3. EARLE, W. R., and NETTLESHIP, A.: Production of Malignancy *in Vitro*. V. Results of Injections of Cultures into Mice. J. Nat. Cancer Inst., **4**: 213–227, 1943.
4. EVANS, V. J.; BRYANT, J. C.; MCQUILKIN, W. T.; FIORAMONTI, M. C.; SANFORD, K. K.; WESTFALL, B. B.; and EARLE, W. R.: Studies of Nutrient Media for Tissue Cells *in Vitro*. III. Whole Egg Extract Ultrafiltrate for Long-Term Cultivation of Strain L Cells. Cancer Res., **17**: 317–324, 1957.
5. FELL, H. B.: The Osteogenic Capacity *in Vitro* of Periosteum and Endosteum Isolated from the Limb Skeleton of Fowl Embryos and Young Chicks. J. Anat., **66**: 157–180, 1932.
6. FELL, H. B.: Skeletal Development in Tissue Culture. *In* The Biochemistry and Physiology of Bone, pp. 401–441. Edited by G. H. Bourne. New York, Academic Press Inc., 1956.
7. GEY, G. O.: Cytological and Cultural Observations on Transplantable Rat Sarcomata Produced by the Inoculation of Altered Normal Cells Maintained in Continuous Culture. Cancer Res., **1**: 737, 1941.
8. GEY, G. O.; GEY, M. K.; FIROR, W. M.; and SELF, W. O.: Cultural and Cytological Studies on Autologous Normal and Malignant Cells of Specific *in Vitro* Origin. Conversion of Normal into Malignant Cells. Acta Unio Internat. Contra Cancrum, **6**: 706–712, 1949.
9. GAILLARD, P. J.: Parathyroid Gland Tissue and Bone *in Vitro*. Exper. Cell Res., Supplementum **3**: 154–169, 1955.

10. GLUCKSMANN, H.: The Role of Mechanical Stresses in Bone Formation *in Vitro*. J. Anat., **76**: 231–239, 1942.
11. GOMORI, GEORGE: Microscopic Histochemistry: Principles and Practice, p. 184. Chicago, The University of Chicago Press, 1952.
12. HEALY, G. M.; FISHER, D. C.; and PARKER, R. C.: Nutrition of Animal Cells in Tissue Culture. X. Synthetic Medium No. 858. Proc. Soc. Exper. Biol. and Med., **89**: 71–77, 1955.
13. HENRICHSEN, E.: Alkaline Phosphatase in Osteoblasts and Fibroblasts Cultivated *in Vitro*. Exper. Cell Res., **11**: 115–127, 1956.
14. HOTCHKISS, R. D.: A Microchemical Reaction Resulting in the Staining of Polysaccharide Structures in Fixed Tissue Preparations. Arch. Biochem., **16**: 131–142, 1948.
15. MCLEAN, F. C., and URIST, M. R.: Bone. An Introduction to the Physiology of Skeletal Tissue. Chicago, The University of Chicago Press, 1955.
16. MOORE, A. E.; SOUTHAM, C. M.; and STERNBERG, S. S.: Neoplastic Changes Developing in Epithelial Cell Lines Derived from Normal Persons. Science, **124**: 127–129, 1956.
17. POMERAT, C. M.: Tissue Culture in Experimental Biology and Medicine. J. Am. Vet. Med. Assn., **129**: 458–462, 1956.
18. POMERAT, C. M.: *In* Wound Healing and Tissue Repair, p. 21. Edited by W. B. Patterson. Chicago, The University of Chicago Press, 1959.
19. RODOVÁ, H.: Observations on the Initial Stages of Ossification *in Vitro*. J. Anat., **82**: 175–182, 1948.
20. ROSE, G. G.: A Separable and Multipurpose Tissue Culture Chamber. Texas Rep. Biol. and Med., **12**: 1074–1083, 1954.
21. ROSE, G. G.: Special Uses of the Multipurpose Tissue Culture Chamber. Texas Rep. Biol. and Med., **15**: 310–312, 1957.
22. ROSE, G. G.: Microkinetospheres and VP Satellites of Pinocytic Cells Observed in Tissue Cultures of Gey's Strain HeLa with Phase Contrast Cinematographic Techniques. J. Biophys. and Biochem. Cytol., **3**: 697–704, 1957.
23. ROSE, G. G.: An Appraisal of a Biological Response by Strain HeLa Cells in Tissue Culture in 100 Human Sera. Cancer Res., **18**: 411–417, 1958.
24. ROSE, G. G.: Time Lapse Cinematographic Evidence for the Redifferentiation of Muscle Cells in Cellophane Strip Cultures as Observed through the AO-Baker Interference Microscope. Read at the Annual Meeting of the Tissue Culture Association, Atlantic City, New Jersey, April 8–9, 1959.
25. ROSE, G. G.: Evidence for an Intercellular Exchange of Cytoplasmic Components between Associated Cells in Tissue Culture. Texas Rep. Biol. and Med. (in press), 1960.
26. ROSE, G. G.; POMERAT, C. M.; SHINDLER, T. O.; and TRUNNELL, J. B.: A Cellophane-Strip Technique for Culturing Tissue in Multipurpose Culture Chambers. J. Biophys. and Biochem. Cytol., **4**: 761–764, 1958.
27. SANFORD, K. K.: Clonal Studies on Normal Cells and on Their Neoplastic Transformation *in Vitro*. Cancer Res., **18**: 747–752, 1958.
28. WOODLIFF, H. J.: A Further Use of Rose's Tissue Culture Chamber. Texas Rep. Biol. and Med., **16**: 380–384, 1958.
29. WOODLIFF, H. J.: Glass Substrate Cultures of Human Blood and Bone Marrow Cells. Exper. Cell Res., **14**: 368–377, 1958.

DISCUSSION

DR. MARSHALL R. URIST, LOS ANGELES, CALIFORNIA: Dr. Rose and Dr. Shindler have perfected a dialysis-cellophane-strip technique for tissue culture of osteoblasts from chick embryonic bone. They have shown very clearly that the cytoplasmic granules visible by phase-contrast and interference-contrast microscopy are the same as the granules that appear in stained histological section, and are therefore structures that exist as such in the living cell.

These investigators performed an experiment in which marrow and periosteum were scraped away from a fragment of embryonic bone and cultured *in vitro*. In place of a plasma clot, they used a strip of cellophane. Within twenty-four hours, the cells, clearly visible as individuals, grew out of the explant onto the cellophane. Nearly all these cells were fibroblastoid, that is, fusiform, broad, flattened, kite-shape, rapidly dividing, and filled with large granules of fat. At from five to seven days, something new appeared in the form of segregation of a special race of cells whose numbers increased to reach a peak from fifteen to eighteen days. These cells were packed with alkaline-phosphatase and periodic acid-Schiff-positive staining cytoplasmic granules; they were smaller but thicker, and more basophilic than fibroblastoid. The authors also observed pinocytosis, a term which means that these cells are heavy drinkers. By these characteristics the authors recognized these cells as osteoblasts.

Twenty-eight years ago, Fell described osteoblasts in cultures with the plasma-clot and hanging-drop technique. She excised the explanted bone and added fresh nutrient fluid and observed that, in the area of the vacancy, the cellular outgrowth then grew inward and differentiated into bone. Fell proved that the outgrowth contained osteoblasts, not only by the morphological characteristics of certain cells, but also by their functional capacity to deposit new bone. This, there can be no doubt, is the final test of whether or not a cell is an osteoblast.

Dr. Rose and Dr. Shindler do not mention the words new bone or organic matrix anywhere in this paper. I am going to ask whether they saw new bone in any of their cellophane-strip cultures, and whether they regard capacity to form new bone as necessary for identification of osteoblasts. Does the cellophane strip encourage migration of cells to a greater distance than the plasma clot

(continued on page 563)

Fractures in Amputees

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Fractures in the stumps of amputated extremities have received little attention in the literature. To our knowledge, very few cases have been reported: six by Saupe, four by Schneider, and one each by Hillebrand and Lanzkron.

Saupe described two fractures of the hip in above-the-knee amputees, one fracture of the hip in a below-the-knee amputee, one fracture three fingerbreadths above the distal end of a femoral stump, and one fracture of the olecranon process of the ulna in a forearm stump. His sixth patient sustained a traumatic amputation at the end of the femur and a higher fracture of the femoral shaft in the same extremity. From a therapeutic standpoint, this fracture behaved like a fracture of a stump.

Schneider reported one intertrochanteric fracture of the femur in a patient who had had a below-the-knee amputation, one subtrochanteric fracture of the femur in a patient with an above-the-knee stump, one fracture of the lateral femoral condyle in a patient who had a below-the-knee stump, and a subcapital fracture of the humerus in a patient who had an above-the-elbow stump.

Hillebrand's patient, an above-the-knee amputee, had an intracapsular fracture of the hip. Lanzkron reported a fracture of the femoral neck in a patient who had a mid-thigh stump. The femoral neck in this patient was fractured during electroshock therapy twice, with an eight-month interval between. The final outcome was avascular necrosis of the femoral head.

MATERIAL OF STUDY

We have reviewed the records of the Mayo Clinic from 1910 through 1958 and found fourteen patients who sustained fractures in amputated extremities.

Fractures in Upper-Extremity Amputees

Three of the fourteen patients had had amputations of their upper extremities. The fractures they sustained were probably not related to their amputations, except in an indirect manner. One patient had sustained bilateral traumatic amputations, one through the middle of the humerus on the right and one through the radius and ulna just above the wrist on the left, in a railroad accident, when he was twenty-two years old. Thirty-two years later, he fractured the surgical neck of the left humerus when he lost consciousness and fell. The second patient had had an amputation between the middle and lower thirds of the left humerus after a shotgun injury at the age of forty-nine years. Eight months later, in an automobile accident, he sustained an impacted fracture of the surgical neck of the left humerus, in addition to multiple injuries to the right hand. The third patient had had a traumatic amputation between the middle and upper thirds of the left humerus when he was thirty-one years old. He did not wear a prosthesis. Twenty-two years later, when falling downstairs, he tried to catch himself with his stump and sustained an open comminuted fracture of the distal end of the stump with medial displacement of a large fragment. A small puncture wound at the level of the fracture was cleaned and dressed; medication was given for the pain, and the stump was strapped to the patient's side for immobilization. He returned to work, as a clerk, two days later.

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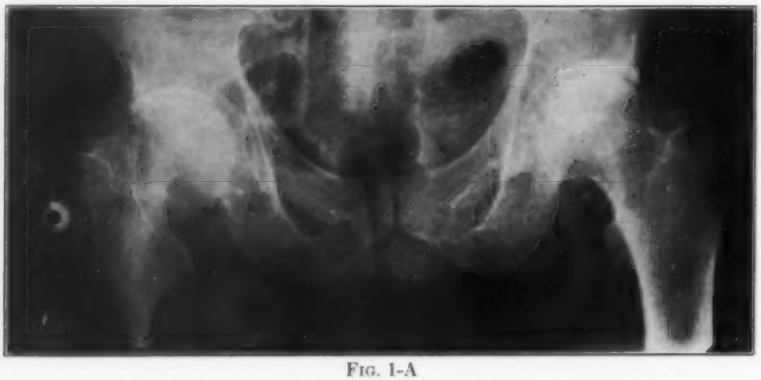

FIG. 1-A

Case 1. Anteroposterior view showing intracapsular fracture of the right femoral neck in a patient who had had bilateral below-the-knee amputations. During closed reduction and fixation, control of the distal fragment was obtained by a Kirschner wire placed through the femoral condyles.

FIG. 1-B

Roentgenogram made six months after fracture shows good union after reduction and internal fixation with a Smith-Petersen nail.

Fractures in Lower-Extremity Amputees

Eleven lower-extremity amputees sustained fractures in their amputated limbs (Table I). Of these patients, seven had had amputations below the knee and four above the knee. Three additional case reports were found in the records of The Mayo Clinic of amputees who had sustained fractures in their opposite, normal limbs because of falls resulting from their amputations, but they are not included in this study.

Of the seven patients who had had below-the-knee amputations, two had lost both limbs below the knee. The average age of these patients when amputation had been performed was forty-four years; at the time of the fractures it was fifty-one years. As might be expected, all fractures were of the femur: five were hip fractures: three, intracapsular fractures of the neck; one, intertrochanteric fracture; and one, subtrochanteric fracture. Two were in the shaft of the femur, and one was in the supracondylar region. One patient (Case 4) sustained multiple fractures.

The average age of the four patients who had had amputations above the knee was forty-one years at the time of amputation and sixty-two years at the time of fracture. Two sustained intracapsular fractures of the femoral neck, the third an intertrochanteric fracture, and the fourth a combined intracapsular,

FIG. 2-A

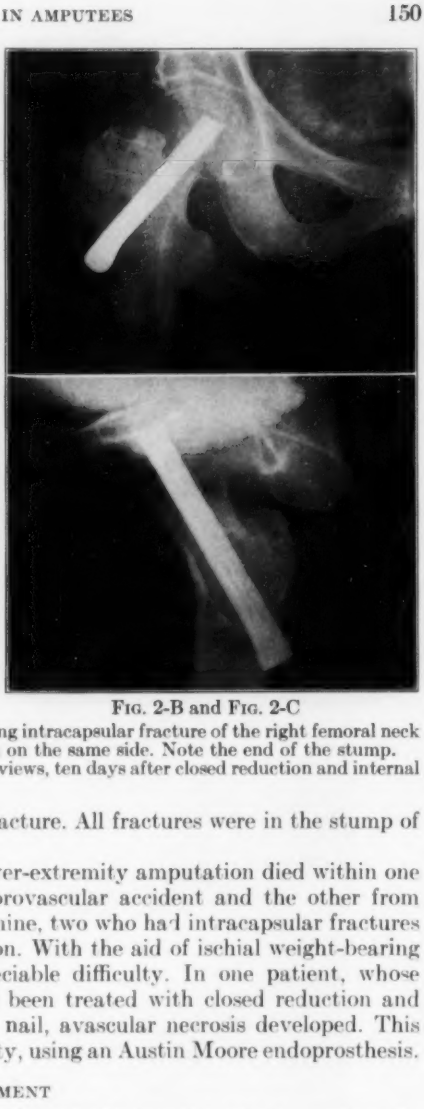

FIG. 2-B and FIG. 2-C

Fig. 2-A: Case 10. Anteroposterior view showing intracapsular fracture of the right femoral neck in a patient having had a mid-thigh amputation on the same side. Note the end of the stump.

Figs. 2-B and 2-C: Anteroposterior and lateral views, ten days after closed reduction and internal fixation with a Smith-Petersen nail.

intertrochanteric, and subtrochanteric fracture. All fractures were in the stump of the amputated limb.

Two of the eleven patients with lower-extremity amputation died within one month after fracture, one from a cerebrovascular accident and the other from pulmonary embolism. Of the remaining nine, two who had intracapsular fractures of the femoral neck did not achieve union. With the aid of ischial weight-bearing prostheses, both walked without appreciable difficulty. In one patient, whose transcervical fracture of the femur had been treated with closed reduction and internal fixation with a Smith-Petersen nail, avascular necrosis developed. This was painful and later required arthroplasty, using an Austin Moore endoprosthesis.

COMMENT

It is most interesting that the prostheses had played a role in causing the accidents, which resulted in fracture in seven of the eleven lower-extremity amputees. In two patients, the exact cause of fracture is unknown. One patient fell while walking with crutches to the bathroom, without her prosthesis. In Saupe's Case 2 the fracture was incurred in the same manner. In one patient, the fracture was incurred during manipulation for sciatic pain by an irregular practitioner of medicine.

There is no reason to assume that fractures in the intact limbs of amputees behave differently from ordinary fractures. Practically, our series demonstrates that the course of hip fractures in patients with below-the-knee stumps deviates little, if at all, from the course of hip fractures with normal limbs, and that these injuries should be treated by conventional methods. The neck fracture of Case 1 and the intertrochanteric fracture of Case 2 healed after internal fixation. The femoral-neck fracture of Case 5 resulted in non-union. In Case 6 avascular necrosis

FIG. 3-A

Case 6. Lateral and anteroposterior views of the below-the-knee stump eight years after amputation.

FIG. 3-B

Anteroposterior view showing fracture of the femoral neck on the side of amputation.

of the femoral head developed after closed reduction and fixation with a Smith-Petersen nail.

The conditions for the healing of femoral-shaft fractures in patients who have below-the-knee stumps are, at least from a theoretical standpoint, very favorable; there is a much shorter lever arm on the distal fragment than when the same fracture exists in a normal limb. However, such femoral-shaft fractures may be difficult to immobilize in a plaster cast. An irreparable flexion contracture of the knee may occur, as in Case 3.

Fractures in above-the-knee stumps seem to heal better than those in normal limbs. Especially was this true when the stump was short. This tendency to heal

FIG. 3-C

Anteroposterior view six weeks after closed reduction and internal fixation with a Smith-Petersen nail.

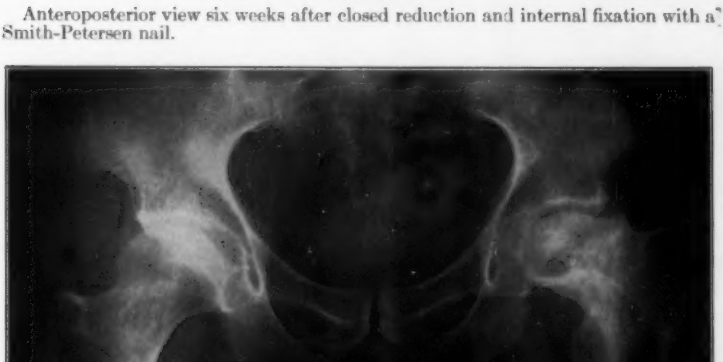

FIG. 3-D

Anteroposterior view showing avascular necrosis of the left femoral head twenty-one months after fracture.

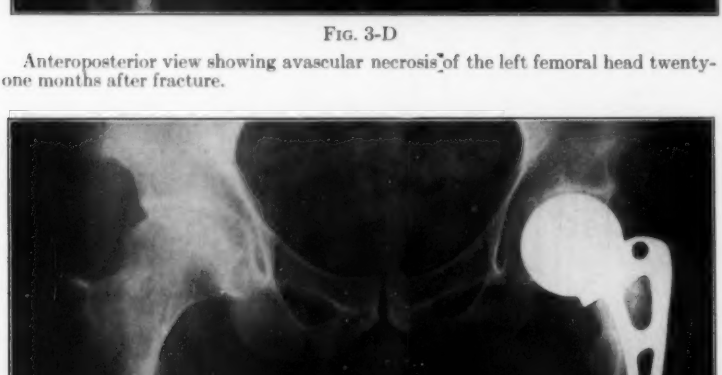

FIG. 3-E

Anteroposterior view showing Austin Moore prosthesis eleven months after insertion.

TABLE I

CIRCUMSTANCES OF AMPUTATIONS AND OF SUBSEQUENT FRACTURES, WITH TREATMENT AND RESULTS

Case	Sex	Age (*Years*)	Circumstances of Amputation Reason	Site	Prosthesis	Age (*Years*)	Interval between Amputation and Fracture	Circumstances of Fracture Cause	Site	Treatment	Results
				Below-the-Knee Amputees*							
1	M	67	Arteriosclerosis	Right	Orthodox**, right	70	3½ yrs.	Fell while alighting from automobile	Subcapital, neck of right femur	Closed reduction with Kirschner wire in distal part of femur, internal fixation with Smith-Petersen nail	Fracture united in 3 mos.; then right ischial weight-bearing prosthesis used 5 mos.; then orthodox prostheses
		70	Gangrene	Left	None, left		4 mos.				
2	M	32	Trauma	Left	Orthodox	32	5 mos.	Fell, 3 wks. after beginning use of prosthesis	Intertrochanteric, left femur	Internal fixation with Blount plate	United in external rotation; good gait with ischial weight-bearing prosthesis
3	F	9	Trauma	Right	Orthodox	54	45 yrs.	Fell on steps	Supracondylar, right femur	Traction and plaster-cast immobilization; after 5 mos., supracondylar amputation	United with posterior displacement and contracture of knee; good gait with ischial weight-bearing prosthesis after below-the-knee amputation
4	F	33	Trauma and residuum of anterior poliomyelitis	Right	Unknown	37	4 yrs.	Unknown	Mid-shaft and subcapital, neck of right femur	Unknown	Mid-shaft fracture healed with some angulation; neck fracture did not heal; ischial weight-bearing prosthesis used
5	M	35	Paraplegia due to injury to cauda equina	Bilateral	Bilateral, orthodox	43	8 yrs.	Manipulation for sciatic pain by irregular practitioner	Femoral neck, right	Skeletal traction followed by immobilization in plaster cast	Non-union; resumed walking using ischial weight-bearing prosthesis on right and orthodox on left
6	M	35	Tuberculosis, foot and ankle	Left	Orthodox	47	12 yrs.	Fell while scuffling	Transcervical, left femur	Closed reduction and internal fixation with Smith-Petersen nail	Nail painful, removed in ten mos.; painful avascular necrosis developed; Moore

7	F	73	Diabetic gangrene	Left Gritti-Stokes	Knee-bearing	75	2 yrs.	Unknown	Upper third, shaft of left femur	Unknown	endoprosthesis gave good result; now uses orthodox prosthesis Died of cerebrovascular accident 1 mo. after fracture
				Above-the-Knee Amputees							
8	M	23	Trauma	Juncture, middle and upper thirds of left femur	Ischial weight-bearing	64	41 yrs.	Fell while walking downstairs	(Comminuted) subtrochanteric, intertrochanteric, and intracapsular, left femur	Skeletal traction for 7 wks., then single spica cast for 1 mo.	Returned to use of prosthesis 4 mos. after injury; all fractures united
9	F	10	Tuberculosis of knee	Middle of left femur	Ischial weight-bearing	49	38 yrs.	Fell when heel caught on rug	Intracapsular, left femoral neck with valgus position	Avoidance of weight-bearing, 2½ mos.	In 2½ mos. resumed use of prosthesis and occupation as secretary
10	F	70	Fibrosarcoma	Juncture, middle and upper thirds of right femur	None at time of fall	72	2 yrs.	Fell while walking with crutches at night	Intracapsular at base of right femoral neck	Closed reduction with Steinmann pin through distal part of stump, internal fixation with Smith-Petersen nail	Union and resumption of use of ischial weight-bearing prosthesis
11	M	62	Diabetic gangrene	Juncture, middle and lower thirds of right femur	Ischial weight-bearing	63	1 yr.	Fell	Intertrochanteric, without displacement	Avoidance of weight-bearing]	Died 5 days after fracture from pulmonary embolism
				Arm Amputees							
12	M	22	Trauma	Middle of right humerus and lower third of left forearm	Not stated	54	32 yrs.	Syncope and fall	Surgical neck, left humerus	Temporary immobilization	United with good alignment
13	M	49	Trauma	Juncture, middle and lower thirds of left humerus	Conventional	50	8 mos.	Automobile accident	Impacted surgical neck, left humerus	Sling and early motion	Resumed use of prosthesis 2 mos. after fracture; good result
14	M	31	Trauma	Juncture, middle and upper thirds of left humerus	None	53	22 yrs.	Fell downstairs and attempted to break fall with the stump	Distal end of stump	Cleaning of small puncture wound, stump bandaged to side	Returned to clerical work after 2 days

* Unless indicated otherwise, (Case 7), all below-the-knee amputations were at site of election.
** Orthodox refers to prostheses not bearing ischial weight.

better was probably due to decreased leverage on the distal fragment. Saupe pointed out that fractures in amputated limbs tend to heal in a relatively short time. The fragments are less disturbed by muscle pull because the insertions of many of the powerful muscles of the thigh are absent. Hillebrand stated that femoral-neck fractures of Pauwels' Type II behave like those of Pauwels' Type I. In Case 8 union was achieved in this severe combined intracapsular, intertrochanteric, and subtrochanteric fracture, even though the fracture of the femoral neck never was accurately reduced. The intracapsular fracture in the above-the-knee stump described by Hillebrand united rapidly, as did the hip fractures in two above-the-knee stumps reported by Saupe. Rest in bed was the only treatment for these three patients.

It has been our practice in treating fractures of the femoral neck by closed reduction and internal fixation to place a Steinmann pin or Kirschner wire through the distal end of the femur. A bow then is fastened to the wire or pin, and by this means the distal fragment can be manipulated and the fracture reduced for fixation with a Smith-Petersen nail. At the end of the operative procedure, the pin or wire is removed.

Slocum pointed out that maintenance of length is of no moment when a fracture occurs in an amputated extremity. He did not favor open reduction or the use of plates or screws where they might not be tolerated in the socket of the prosthesis. Slocum believed also that the use of pins or wires in the stump is undesirable. He stated that although open operation is permissible in locations which will not lie within the socket of the prosthesis, closed reduction without fixation is to be preferred even there. Gillis noted that many prostheses are of the ischial weight-bearing type and that the best splint for the fracture may well be the patient's artificial limb. He believed that nailing the fractured neck of a femur is unnecessary. He stated that bone union sometimes occurs in these fractures without the introduction of nails, and that if it does not occur, painless fibrous union suffices.

We have observed no ill effects from the temporary use of skeletal traction or from internal fixation of femoral-neck fractures with Smith-Petersen nails, and plan to continue using such fixation, particularly in below-the-knee stumps. In fractures of the femoral neck, bone union in good position should be ensured when possible. We believe that this allows the patient better control of his prosthesis with less discomfort than does fibrous union. In our two cases (Cases 4 and 5) of fibrous union of the femoral neck, one patient had been treated with traction alone and the other with plaster-of-Paris immobilization. Although both of these patients got along well with ischial weight-bearing prostheses, it is logical that a patient with fibrous union of a fracture would have less control over his prosthesis than he would if he had rigid bone union of the femoral neck. None of the patients in this series used suction-socket prostheses. It seems reasonable to assume, however, that a suction-socket appliance could probably not be used if the fracture of the femoral neck failed to unite with bone.

Various accidents caused the fractures in this series. One fracture of the femoral neck occurred during manipulation for sciatica by an irregular practitioner of medicine. One patient with residual paralysis from anterior poliomyelitis (Case 4) said that she tended to fall frequently because of her prosthesis, and in the course of years, she had sustained two other fractures in different extremities. Two patients fell on steps and two others fell because of difficulty with rugs at home. One patient sustained a fracture involving the intertrochanteric region three weeks after receiving his appliance (five months after amputation) before he became accustomed to using it.

Twisting of the stump within the prosthesis at the time of the fracture was noted by at least two patients (Cases 5 and 8). Two patients sustained cervical fractures of the femur while falling backward. In two others the uncontrolled prosthesis seemed to act as a long lever and produced fracture of the femoral shaft at a point not actually encompassed in the appliance, the edge of the prosthesis

functioning as a fulcrum. Osteoporosis of disuse was present in all stumps and no doubt played a part in producing the fracture. Amputation prior to adolescence usually is followed by hypoplasia of the bones on the affected side, as is evidenced in Case 9.

REPORT OF CASES

The following reports illustrate the more common problems encountered and the results achieved.

CASE 1. In March 1954, at the age of sixty-seven years, the patient had a below-the-knee amputation of the right leg because of diabetic gangrene (Table I). In August 1957, at the age of seventy years, he had a below-the-knee amputation of the left leg, also because of diabetic gangrene. In December 1957, he fell on his right hip when getting out of a car while wearing only the right artificial limb and using crutches. He sustained an intracapsular fracture of the neck of the right femur (Fig. 1-A). Closed reduction of the fracture was accomplished after a Kirschner wire was placed through the femoral condyles to aid in manipulation. A Smith-Petersen nail then was inserted. The fracture was healed three months later (Fig. 1-B), and the patient resumed walking, using an ischial weight-bearing prosthesis on the right side. Five months after that, the prosthesis was altered so that ischial weight-bearing was no longer used.

CASE 10. In May 1953, when seventy years old, the patient had a mid-thigh amputation because of a fibrosarcoma that involved the right knee (Table I). In December 1955, while walking to the bathroom at night with crutches, but without her prosthesis, she caught one crutch on a chair and fell. An intracapsular fracture of the neck of the right femur resulted (Fig. 2-A). A Steinmann pin was placed through the end of the femoral stump and a bow was clamped to the pin. The fracture was reduced after the patient had been placed on a fracture table, and fixation was secured by a Smith-Petersen nail (Figs. 2-B and 2-C). Pathological fracture was ruled out by biopsy. The patient wrote (1959) that healing occurred and that she had resumed use of original prosthesis. She left the hospital two and one-half weeks after fixation of the fracture and did not return for re-examination.

CASE 6. In 1944, at the age of thirty-five years, the patient had an amputation (Table I) six inches below the inferior pole of the left patella because of tuberculosis of the left foot and ankle (Fig. 3-A). He subsequently walked well with a conventional prosthesis without ischial weight-bearing. Twelve years later (in 1956), wearing his prosthesis, he fell backward while scuffling and sustained a basilar transcervical fracture of the left femur (Fig. 3-B). The fracture was reduced and fixed with a Smith-Petersen nail (Fig. 3-C). The fracture healed in three months, and the patient started to use his prosthesis again three months later. At ten months pain was noted, and, subsequently, roentgenograms showed the development of avascular necrosis (Fig. 3-D). In November 1957, twenty-one months after the fracture, the femoral head was excised and an Austin Moore endoprosthesis inserted (Fig. 3-E). Four months later the patient was walking without pain and was wearing his prosthesis. When last seen here, in October 1958, the patient walked without appreciable difficulty. The hip extended to 180 degrees and flexed to 80 degrees, but there was almost no rotation.

CASE 8. In 1917, at the age of twenty-three years, the patient sustained a traumatic amputation of the left thigh between the middle and upper thirds (Table I). He became a brace maker and had no trouble with his ischial weight-bearing prosthesis, although his gait never was one that could be classified as good. Forty-one years after his amputation, at the age of sixty-four (May 1958), the heel of his prosthesis caught as he was walking downstairs; consequently, he missed a step and fell. The patient recalled that as he fell the stump came partially out of the prosthesis and that the prosthesis produced a marked rotary effect on the stump. Roentgenograms after this injury revealed comminuted intracapsular, intertrochanteric, and subtrochanteric fractures of the stump of the left femur (Figs. 4-A and 4-B). Skeletal traction, using a Kirschner wire through the end of the stump, was instituted and continued for seven weeks, but the rather marked rotation of the femoral head never was corrected. A plaster-of-Paris spica cast that encased the stump was applied and worn for another month. External support was then discontinued, but the patient was advised to refrain from the use of his prosthesis until healing of all fractures was complete. This he refused to do, but over a period of three months he gradually resumed weight-bearing with his prosthesis and returned to work. Despite the fact that union of the femoral-neck fracture was not achieved by six months, roentgenograms (Figs. 4-C and 4-D) made nine months after injury showed probable healing of all fractures, and those made eighteen months (Figs. 4-E and 4-F) after injury showed definite firm union—including that of the femoral neck, which never had been reduced accurately. The patient said that he has no discomfort and no difficulty in using his prosthesis, which always has been of the ischial weight-bearing type.

CASE 9. The patient had a mid-thigh amputation for tuberculosis of the left knee at ten years of age (1910), and thereafter walked with crutches without a prosthesis until 1919 (Table I). In a fall six months after the amputation she had injured the stump, but no fracture had occurred at

FIG. 4-A

FIG. 4-B

Fig. 4-A: Case 8. Anteroposterior view showing comminuted intracapsular, intertrochanteric, and subtrochanteric fractures of the left femur in the amputated stump.

Fig. 4-B: Lateral view showing same fractures. The femoral head is tilted anteriorly almost 90 degrees.

FIG. 4-C

FIG. 4-D

Anteroposterior and lateral views nine months after injury. All fractures appear to be uniting, including that of the femoral neck, which was never reduced accurately.

that time. In 1911, while using her crutches and playing with other children, she fell and sustained an undisplaced fracture of the right tibia. In the period from 1919 to 1920 she learned to walk with a prosthesis, with minimum limp. At that time she said that she did not fall more often than anyone else, and that she learned how to fall without injuring herself. However, she never had a perfectly fitting socket and always had difficulty throwing the lower part of the leg forward with her fifteen-centimeter stump. Using a conventional ischial weight-bearing limb with two shoulder straps, she was able to extend the knee of her prosthesis by shrugging her shoulders.

In 1950, at forty-nine years of age, the patient stepped back while ironing at home. Her heel caught on a large rug (she does not remember which heel) and she fell backward landing on her buttocks. As she was falling her prosthesis was driven upward but the stump remained stationary. As a result the anterior edge of the socket impinged sharply against the upper end of the femur. The patient recalled that she felt the bone break as she was falling. Roentgenograms disclosed a Pauwels' Type I, intracapsular fracture of the left femoral neck. Treatment consisted in rest in bed and then crutch walking without wearing the prosthesis for two months. Thereafter, use of the same artificial limb was resumed. Weight-bearing on the prosthesis was very painful for the first two or

FIG. 4-E

FIG. 4-F

Anteroposterior and lateral views eighteen months after injury. All fractures are firmly united.

three weeks, but the pain subsequently disappeared and the patient returned to her occupation as a secretary soon after she resumed the use of her prosthesis.

SUMMARY AND CONCLUSION

Fractures in the amputated extremities of fourteen amputees have been reported. Three of the patients had sustained amputations of the upper extremities; eleven, of the lower extremities. Healing of fractures in amputees does not differ materially from healing in persons who have not had amputations, with one possible exception: fractures of the upper part of the femur sustained by patients with above-the-knee stumps seemed to unite faster and better as a result of the shortened leverage of the distal fragment.

REFERENCES

1. GILLIS, LEON: Amputations, p. 320. London, William Heinemann, Ltd., 1954.
2. HILLEBRAND, H.: Schenkelhalsfraktur im Amputationsstumpf. Chirurg, **13**: 542–545, 1941.
3. LANZKRON, JOHN: A Case of a Hip-Fracture Occurring During Electric Shock Treatment in a Patient With an Amputation Stump. Am. J. Psychiat., **111**: 702, 1955.
4. SAUPE, H.: Stumpfbrüche. Arch. Orthop. u. Unfall-Chir., **40**: 533–537, 1940.
5. SCHNEIDER, WERNER: Amputationsstumpf-Frakturen. Zentralbl.f.Chir., **67**: 1579–1582, 1940.
6. SLOCUM, D. B.: An Atlas of Amputations, pp. 287–288. St. Louis, The C. V. Mosby Co., 1949.

A Brace Attachment to Permit Knee Mobilization in Hip Spicas

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The tendency for stiffness to develop in a knee which must remain in plaster for several months, following a hip arthrodesis, has always been a problem of management. Cutting out the back of the spica cast below the knee permits guarded knee exercises to be carried out. However, this procedure exposes the hip to the danger of unwarranted rotation, and therefore requires close supervision during the exercise period. We have resorted to the expedient of cutting off the entire cast below the knee, and substituting a double-upright toe-to-groin brace. This brace supports the leg fully in flexion (Fig. 1). Application of the brace is carried out six weeks after the hip arthrodesis has been performed. Knee exercises, to be described, are begun the day after.

The brace is attached to the spica by means of plaster bandages. In order to facilitate this, a cross piece of aluminum is riveted to the top of each side bar of the brace. Extra strips of plaster bandage are carried around each side bar at the level of the lower edge of the cast, just above the knee, so as to provide secure fixation at that point. Special care must be taken to align the hinge of the brace with the patient's knee joint. This hinge has a slip lock. The ankle joint is free, with caliper extensions to fit into rectangular sockets in a shoe. While the patient remains in bed, a soft type of shoe or sneaker is used for comfort. A shin piece, made of plaster well molded to the leg and padded with felt, is attached to the

FIG. 1

Brace as attached to hip spica, showing plaster shin piece and shoe for use in bed. Note knee flexion obtained.

FIG. 2

FIG. 3

Fig. 2: The brace for walking. This patient used shoulder straps to help support weight of his artificial leg.

Fig. 3: Showing ring at back of brace, for attachment of exercise apparatus, hooked up out of the way for walking.

brace with straps, in order to distribute pressure evenly over the tibia anteriorly, as illustrated. A standard knee cap may also be employed.

When ambulation is to be started, a new cast is applied to the patient. This is a single hip spica, ending just above the knee. As soon as the plaster has set, the same brace is attached to this cast in the manner that has just been described. For walking purposes, a regular shoe is used on the caliper (Figs. 2 and 3). The patient still wears his soft shoe when he goes to bed at night.

Exercises for the knee are carried out with the patient lying prone across his bed (Fig. 4). A cross bar is clamped to the Balkan frame over the point where he will lie during his exercises, and a rope is passed through two pulleys on this bar. One end of the rope is attached to the back of the brace, by means of a snap hook. The other end of the rope is supplied with a handle convenient to the patient's reach. By pulling on this handle, he flexes his knee. He is instructed always to use his leg muscles at the same time. While flexion remains short of about 60 degrees, a webbing strap is carried behind the knee to serve as a fulcrum, and to prevent the patient from lifting his leg off the bed as he pulls. The strap anchors

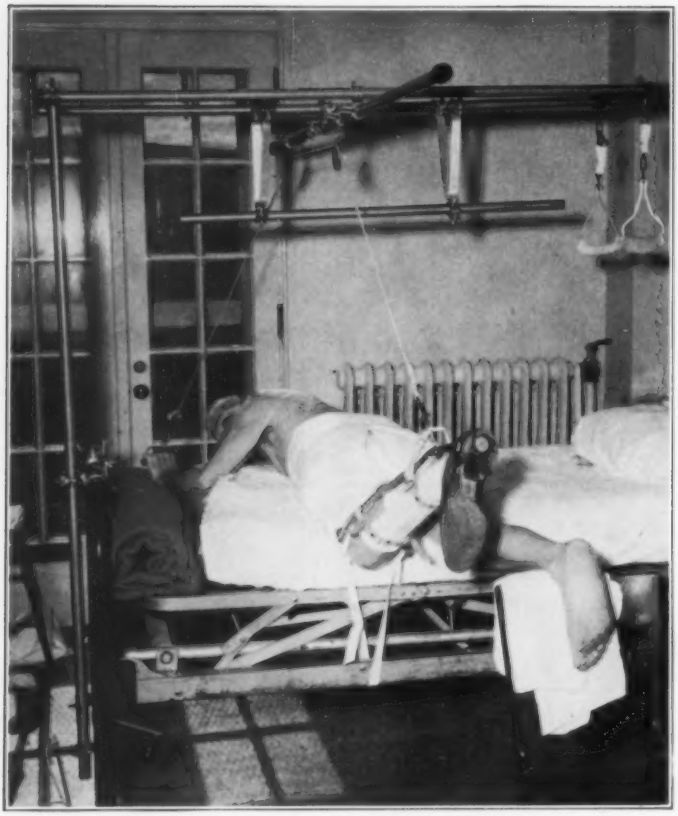

FIG. 4

The exercise apparatus in use. Note webbing strap which holds the knee down during early flexion exercises.

the knee down to a side rail of the bed. It should be well padded with felt in the popliteal space.

In time the patient becomes able to flex his knee by use of his leg muscles alone. At this stage, resistance exercises are started—for both knee flexors and extensors—by means of appropriate weights and pulleys.

Patients are able and eager to carry out their knee exercises several times a day, with no supervision after the apparatus has been hooked up by a nurse. It gives them something to do, and it affords them a welcome means of checking their own progress. They gain excellent knee function by the time that the hip spica is due for final removal.

We have constructed these braces from parts of other braces which had been discarded, and we have used them with great satisfaction, both to ourselves and the patients, over the past three years.

Avascular Necrosis of the Capitellum Humeri (Panner's Disease)

A Report of a Case

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In May 1956 we came across a case of avascular necrosis of the capitellum of the humerus in an eight-year-old boy. We had never seen this center affected before, and in checking with several local roentgenologists and orthopaedists, we found that few had seen such a case. In searching the literature we found that Panner was first to report this condition in 1927. In the years since, several other reports have appeared in the European literature [2,3,4,5] and some in the American literature [1,5,6]. It is probable that this condition is much more common than is indicated by the number of cases reported, since some may have eluded diagnosis and others may not have been recorded.

REPORT OF A CASE

T. N., an eight-year-old white boy, was seen in 1956, ten days after a fall in which he injured his right elbow. The fall was minor, and there was some question in the parents' minds whether it was even of significance. When we saw the patient he was complaining of pain and stiffness in his right elbow. On physical examination there was definite swelling in the joint, and motion was limited about 25 degrees in both flexion and extension. The temperature was normal, the white-cell count showed mild elevation, the sedimentation rate was normal, the urinalysis was normal, the Venereal Disease Research Laboratory test was non-reactive, and the tuberculin skin tests were negative. The elbow was aspirated, and about five cubic centimeters of clear yellow fluid was withdrawn. The fluid was cultured for the usual pathogens and for acid-fast organisms; all cultures were negative. Roentgenograms of both elbows at this time showed beginning fragmentation of the right capitellum (Figs. 1-A through 2-B).

The right arm was immobilized for three weeks in a plaster splint, with the elbow at 120 degrees; during this time all pain and swelling subsided. At the end of three weeks a new plaster splint was made which the patient wore for protection during the day and removed at night so that the elbow could be exercised. He wore this type of splint for the next six months when engaging in vigorous activities; at the end of that time no protection was used. Roentgenograms made frequently first showed progressive fragmentation of the capitellum and later showed healing. Figures 3-A and 3-B are representative roentgenograms made during the course of the disease.

At the time of writing the boy is asymptomatic with 5 degrees of limitation of both flexion and extension. The roentgenograms of the elbow made three years after the onset of symptoms (Figs. 4-A and 4-B) show complete revascularization of the capitellum but with some flattening and irregularity at the joint margins.

REVIEW OF THE LITERATURE

Panner first reported this condition in 1927. In 1956 Laurent and Lindstrom reviewed the literature and cited twenty-three cases; since their report one other has been published [6]. Of the twenty-four cases reported, twenty-two were in boys, and two in girls. The age of the patient was usually from seven to ten years, although one patient was even younger.

All reports indicated that the condition passes through stages which are not unlike the stages seen in osteochondrosis of other centers, such as in Legg-Calvé-Perthes', Köhler's, and other diseases. However, since the elbow is a non-weight-bearing joint, the capitellum was reconstituted quite well in all cases reviewed, and the only residuum noted was slight change around the joint margins and some flattening of the contour of the capitellum.

The etiology of this condition in the elbow is probably the same as the etiology of avascular necrosis elsewhere. These changes occur at a time when epiphyseal activity is at its greatest. Most authors believe that endocrine factors play an important role, causing a loss of circulation to the epiphysis. The question

FIG. 1-A

FIG. 1-B

Anteroposterior and lateral roentgenograms made ten days after the onset of symptoms. Note beginning fragmentation in the right elbow, compared with the left, normal elbow in Figs. 2-A and 2-B.

FIG. 2-A

FIG. 2-B

Anteroposterior and lateral roentgenograms of the normal (left) elbow.

of trauma naturally arises since trauma usually heralds the discovery of this condition; reports indicate that boys are affected eleven times as frequently as girls. It is doubtful that trauma could account for this much difference, even though boys are more prone to trauma. Also, there is a report in the literature of bilateral involvement [4], and another where avascular necrosis occurred simultaneously in the head of the femur, in the patella, and in the capitellum [5]. Therefore, most authors believe that the primary etiological factor is an endocrine disturbance but the exact nature of the disturbance is far from settled.

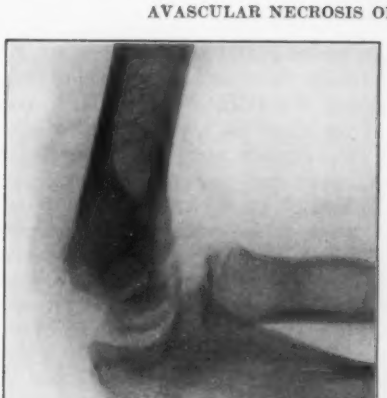

FIG. 3-A

FIG. 3-B

Lateral roentgenograms made ten months after onset of symptoms. Note marked fragmentation of the right elbow in Fig. 3-A, as compared with the left (normal) elbow in Fig. 3-B.

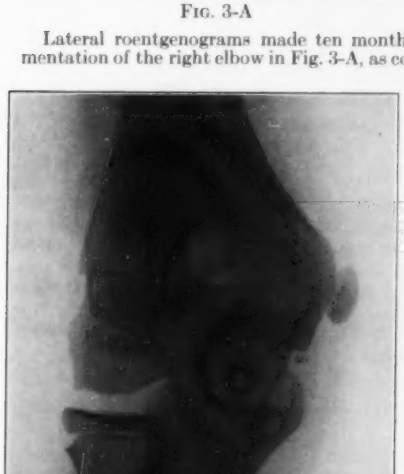

FIG. 4-A

FIG. 4-B

Anteroposterior and lateral roentgenograms, made three years after onset of symptoms, show complete reconstitution of the capitellum, but with some residual flattening, slight changes around the joint margins, and a few small fragments of extraneous calcification.

In most of the reported cases treatment consisted in immobilization for a short period until pain and swelling disappeared; this varied from a week or two to four or five weeks, after which the child was merely admonished to refrain from injuring his elbow. Generally speaking, the duration of immobilization appeared to have little influence on the end result.

DISCUSSION

Our patient's elbow was immobilized completely for approximately three weeks; at the end of that time most of the pain and swelling had subsided, albeit he still did not have complete motion. This phenomenon often occurs in Legg-Calvé-Perthes' disease, where the patient complains of pain around the hip and

very definite limitation of motion; but after a period of rest and, possibly, traction most of this disappears. Often with Legg-Calvé-Perthes' disease there is limitation of motion of the hip, which persists at the end of treatment two or three years later, similar to the limitation of motion of the elbow that was observed in our patient. Reconstitution to nearly normal occurs much more frequently in the capitellum than it does in the hip joint. We immobilized our patient's arm during the daytime for six months because we had had no experience with the disease, and the roentgenogram suggested that this was a serious condition. We did, however, allow him to have his arm out of the splint every night, when he was less active. This amount of activity maintained his elbow in good condition. Stiffness did not increase; in fact, most of the limitation of motion disappeared. After reviewing the literature, it would appear that it makes little difference whether or not this period of protection is carried out.

The center of ossification for the capitellum appears between the first and eighth months of postnatal life and fuses with the main body of the humerus at about fifteen years of age. The center of ossification for the trochlea appears between the ages of seven and nine years and fuses at about fourteen. If this disease is due to a disturbance of the circulation, which seems most probable, one wonders what happens to the trochlea, which is still cartilaginous and not visible on roentgenograms at the age when Panner's disease occurs. The trochlea is derived from the same cartilaginous mass as the capitellum and any disturbance in the circulation should affect both the capitellum and the trochlea equally. Panner's disease is rather uncommon, but it would be interesting to follow these patients to adulthood to determine if any change occurs in the joint margins of the trochlea since this cartilaginous mass must suffer from avascular necrosis along with the capitellum without being recognized on the roentgenogram because of lack of ossification of the trochlea at that time.

CONCLUSION

A case of avascular necrosis of the capitellum humeri is reported in an eight-year-old boy; the condition resembles avascular necrosis in other epiphyses. Although its appearance on the roentgenogram is quite ominous, the prognosis is good with a minimum of treatment. However, definite changes in the roentgenological appearance of the elbow in the area of the capitellum usually persist after complete revascularization has occurred. It would be interesting to follow patients with this condition far into adulthood to see how these mildly damaged elbows stand the wear and tear of use. It would also be interesting to see if when the trochlea finally becomes completely ossified it too shows evidence of having been damaged by avascular necrosis at a time when it was almost purely cartilaginous.

REFERENCES

1. Elward, J. F.: Epiphysitis of the Capitellum of the Humerus. J. Am. Med. Assn., **112**: 705–708, 1939.
2. Hermodsson, Ivan: On the Problem of Trauma and Aseptic Osteonecrosis. Acta Radiol., **28**: 257–268, 1947.
3. Lange, Jean: Aseptic Necrosis of the Capitellum of the Humerus. Panner's Disease. Acta Chir. Scandinavica, **108**: 301–303, 1954.
4. Laurent, L. E., and Lindstrom, B. L.: Osteochondrosis of the Capitellum Humeri; Panner's Disease. Acta Orthop. Scandinavica, **26**: 111–119, 1956.
5. March, H. C.: Osteochondritis of the Capitellum (Panner's Disease). Am. J. Roentgenol., **51**: 682–684, 1944.
6. Omer, G. E., and Conger, C. W.: Osteochondrosis of the Capitulum Humeri (Panner's Disease). United States Armed Forces Med. J., **10**: 1235–1241, 1959.
7. Panner, H. J.: An Affection of the Capitulum Humeri Resembling Calvé-Perthes' Disease of the Hip. Acta Radiol., **8**: 617, 1927.
8. Panner, H. J.: A Peculiar Affection of the Capitulum Humeri, Resembling Calvé-Perthes' Disease of the Hip. Acta Radiol., **10**: 234–242, 1929.
9. Schaefer, R. L.; Strickroot, F. L.; and Purcell, F. H.: The Endocrine Implication of Juvenile Chondro-Epiphysis. J. Am. Med. Assn., **112**: 1917–1919, 1939.
10. Smith, L. A.: Epiphysitis of Adolescents, with Special Reference to Etiology. Am. J. Roentgenol., **22**: 127–137, 1929.

Intramedullary Lipoma of Bone

Report of a Case

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One of the rarest benign tumors of bone is the intramedullary lipoma. A few confirmed cases have been reported in the literature, and there are vague references to other possible cases [6, 7]. Probably, the first recorded case, a tumor involving the shaft of the femur, was presented by Brault. Wehrsig described a large lipoma of the proximal part of the fibula. More recently, Dickson and associates recorded a tumor which eroded a great portion of the distal metaphysis of the tibia. Caruolo and Dahlin described a lipoma of the proximal part of the ulna, and later Dahlin added another involving the left frontal bone. The latest case encountered was a lipoma of the calcaneus described by Child. To this total of six cases found in the literature, we wish to add a case we believe to be a lipoma involving the distal portion of the tibia.

The patient was a white male, fourteen years old, who had been well until April 30, 1955, when he fell while roller skating, and sustained an oblique fracture of the distal third of the right tibia. This fracture healed satisfactorily, and on July 21, 1955, all external support was discontinued (Figs. 1 and 2).

The patient had no complaints relative to the lower part of the right tibia until September 1957, when he noticed the gradual onset and increasing severity of vague pain in the lower part of the right leg, especially noticeable on activity. At examination on October 8, 1957, the only positive finding was localized tenderness over the tibia, approximately three inches above the ankle joint. Roentgenographic examination showed a well defined translucent area, measuring 3.0 by 1.5 centimeters, located centrally in the distal third of the tibia (Fig. 3). There was no evidence of peripheral sclerosis or periosteal reaction. There was no erosion or expansion of the adjacent cortex. Roentgenographic survey of the skeleton failed to reveal other similar lesions. The serum calcium, phosphorus, and alkaline-phosphatase determinations were within normal limits.

On November 27, 1957, a window measuring approximately 3.0 by 1.5 centimeters was made

Fig. 1

Fig. 2

Fig. 1: Roentgenogram made on April 30, 1955, showing an oblique fracture of the distal part of the right tibia.

Fig. 2: Roentgenogram made on July 17, 1955, showing union of the fragments of the fracture that had occurred two and one-half months previously.

FIG. 3

FIG. 4

Fig. 3: Roentgenogram made on October 8, 1957, showing a well defined translucent area in the distal third of the right tibia.

Fig. 4: Roentgenogram made on January 6, 1959, showing a diffuse healing reaction around the site of the previous defect.

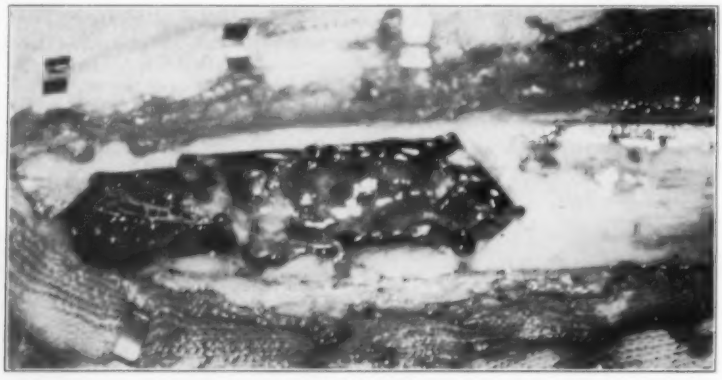

FIG. 5

A lobulated and encapsulated mass of fatty tissue lying free in the medullary cavity of the distal part of the tibia.

in the cortex of the distal part of the tibia over the site of the lesion. A well encapsulated, lobulated mass of fatty tissue was encountered within the medullary cavity (Fig. 5). This mass shelled out in one piece and kept its form (Fig. 6). Chips of homogenous bone were packed into the defect, and the wound was closed. The surgical wound healed primarily. Roentgenographic examination on January 6, 1959, showed a diffuse, healing reaction about the site of the previous defect (Fig. 4). When last seen on April 21, 1959, the patient was working as a bus boy and had no complaints.

Microscopic examination revealed a homogeneous field of fat cells, with occasional fibrous septae and very few small and underdeveloped bone trabeculae in one small portion of the specimen (Fig. 7).

DISCUSSION

It is possible that this lesion may represent a lipoma of bone, or it may represent a disturbance in the healing process of the fracture, such as fatty degeneration of the intramedullary callus. The latter view is supported by the following observations: (1) the lesion was located at the site of the previous fracture; (2) there

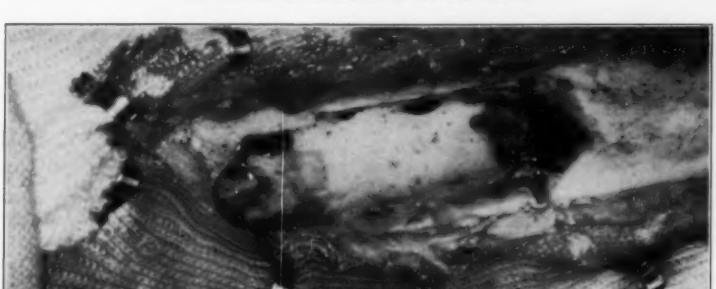

FIG. 6

The medullary cavity of the distal part of the tibia after the lipoma was shelled out in one piece.

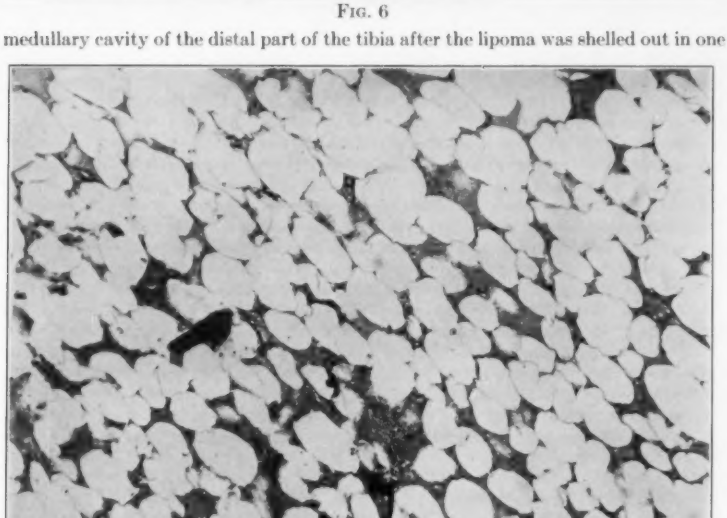

FIG. 7

Photomicrograph of the lipoma located in the distal part of the tibia, showing a homogeneous field of fat cells and very occasional underdeveloped trabeculae (hematoxylin and eosin, × 100).

was a suggestive area of decreased density seen on the roentgenogram made two and one-half months after fracture; (3) there were a very few atrophic trabeculae found in one small portion of the lesion, a finding considered unusual in a lipoma, but this does not necessarily rule out a lipoma; (4) there was no evidence of erosion or expansion of the cortex, as would be expected with a new growth, but this does not necessarily preclude neoplasia since the lesion was small. All these factors could be coincidental with the concurrent existence of a lipoma.

There are two significant points in favor of neoplasia. These are: (1) there was a period of twenty-nine months from the time of fracture to the onset of subjective discomfort and localized tenderness at the site of the lesion; and (2) the lesion was well encapsulated and readily peeled out from the surrounding intramedullary tissue. We conclude that the diagnosis of lipoma is justified on the grounds listed.

Microscopic sections were reviewed by Dr. Louis Lichtenstein, Dr. Sherman S. Coleman, Dr.

Clinton L. Compere, and Dr. Harley Sigmond; these observers concurred in the diagnosis of intramedullary lipoma.

REFERENCES

1. Brault, A.: Des Tumeurs. *In* Manuel d'Histologie Pathologique. By V. Cornil and L. Ranvier. Ed. 3. Vol. I, pp. 393–395. Paris, Baillière et Cie., 1901.
2. Caruolo, J. E., and Dahlin, D. C.: Lipoma Involving Bone and Simulating Malignant Bone Tumor: Report of a Case. Proc. Staff Meet., Mayo Clin., **28**: 361–363, 1953.
3. Child, P. L.: Lipoma of Os Calcis. Report of a Case. Am. J. Clin. Pathol., **25**: 1050–1052, 1955.
4. Dahlin, D. C.: Bone Tumors, pp. 90–93. Springfield, Illinois, Charles C. Thomas, 1957.
5. Dickson, A. B.; Ayres, W. W.; Mason, M. W.; and Miller, W. R.: Lipoma of Bone of Intra-Osseous Origin. J. Bone and Joint Surg., **33-A**: 257–259, Jan. 1951.
6. Geschickter, C. F.: Lipoid Tumors. Am. J. Cancer, **21**: 617–641, 1934.
7. Haas, S. L.: Bones. *In* Lewis' Practice of Surgery. Vol. II, Chap. 1, p. 15. Hagerstown, Maryland, W. F. Prior Co., 1936.
8. Wehrsig: Lipom des Knochenmarks. Centralbl. f. Allg. Pathol. u. Pathol. Anat., **21**: 243–247, 1910.

DISCUSSION

Hematogenous Pyogenic Vertebral Osteomyelitis

(*Continued from page 436*)

I had the honor of being co-author of a paper presented to this body in 1952 in which we analyzed a great variety of vertebral-body lesions treated at Johns Hopkins Hospital in the period from 1926 through 1951 and I believe that we showed the great value of early biopsy as an essential to accurate therapeusis. I am convinced by my experience therein and since that time that exploration and drainage of such lesions are both safe and beneficial. This experience applies not only to pyogenic lesions, but to tuberculosis as well, for absorption of a considerable abscess cavity, extending one centimeter or more in width beyond the vertebral margins in the anteroposterior view, is a slow and tedious and, sometimes in adults, a hazardous procedure without evacuation or drainage to collapse the cavity. This is almost the only respect in which I seem to differ with the authors, because their eight cases with drainage seem to have occurred chiefly before antibiotic days, and they now apparently rely on needle biopsies and antibiotics.

I agree with them that, given proper rest and support, the long-term healing is sound, and, rarely, if ever, is operative fusion required as an accessory measure.

Editorial

PLASTICS AND BONE REPAIR

Reconstructive surgery of the skeleton has made great strides in recent years with improved methods for internal fixation and bone-grafting and, more recently, the development of endoprostheses. Despite this progress, few will deny the shortcomings of many present-day surgical procedures, particularly those used for the treatment of certain difficult fractures; for the repair of large bone defects; and for the arthrodesis of joints in which the magnitude of the stresses and the anatomy of the skeleton render the operative procedure formidable, the convalescence prolonged, and a good result far from assured. Surely, all would welcome a technique for internal fixation suitable for all bones and joints which would eliminate the need for external immobilization, the need for a permanent surgical implant, and the need for bone grafts to stimulate osteogenesis.

Although plastics have been used in reconstructive surgery as inert and insoluble permanent implants, they have proved to be of limited value. Recently, the fascinating and tantalizing suggestion has been made that a polyurethane polymer, which forms a rigid sponge-like mass, can be used as both an adhesive and a replacement for bone to secure such strong and rigid fixation that normal activity without external support can be resumed almost immediately after operation. But more than this—by dint of its spongelike structure and physicochemical properties—this plastic is said to furnish a scaffolding comparable to that supplied by a bone graft, into which new bone will grow. Still more extraordinary is the claim that this substance is slowly absorbed, as it is invaded by bone, to be eliminated without adverse effects on the local tissues or other organs. This indeed would appear to approach the ultimate for reconstruction of the skeleton.

It is not surprising that reports concerning the use of this polyurethane polymer at several recent surgical meetings in America have aroused intense worldwide interest. Because of this great interest, symposia were arranged in January of this year by The American Academy of Orthopaedic Surgeons and the Orthopaedic Research Society to acquaint orthopaedic surgeons with the latest information, both clinical and experimental.

To those who attended these meetings the conflicting nature of the data presented and the wide divergence of opinions expressed were apparent in the presentations and the discussions which followed. For those not present at these meetings, publication of well documented information is, of course, needed. The Board of Associate Editors of The Journal is keenly aware of this need and keenly aware also of its duty to keep to the sometimes narrow path that lies between ultraconservatism on the one side and the publication of results not adequately documented or tested by time on the other. The more exciting the innovation, the more the criticism of the editorial decision. Depending on viewpoint, a decision to delay publication will be considered either as obstruction to progress or as proper scientific discipline.

Three papers concerning this polymer have been submitted to the Board of Associate Editors for publication—one very favorable clinical follow-up study, one very unfavorable clinical follow-up study, and one report of animal experimentation. Prepared for presentation from the podium, these papers fail to document the findings and the conclusions drawn; at the same time they indicate seemingly irreconcilable differences. Publication of such conflicting, if not opposite, results in the absence of essential supporting data would, in the opinion of the Board of Associate Editors, serve no useful purpose. With full realization of the great current interest in this controversial subject the Board has voted not to publish these papers in the forms presented but to make every effort to get the facts and to publish these as promptly as possible. The authors of these papers have expressed their willingness to cooperate in this endeavor.

It should be emphasized that this decision is based not on opinion relative to merits or demerits of this material, but on the simple fact that information concerning the actual present status of this material is not sufficient to warrant publication. The Board of Associate Editors, in company with orthopaedic surgeons the world over, awaits with interest more scientific data concerning the capacity of the polymer to be replaced by bone, the strength of its bond to bone, the reaction of the local tissues to this foreign body, and, finally, the long-term effects of this polymer and its degradation products on the organism as a whole.

Proceedings

WESTERN ORTHOPEDIC ASSOCIATION

As Prepared by the Editorial Committee: Ivar J. Larsen, M.D., *Chairman*; Robert Mazet, Jr., M.D., John R. Schwartzmann, M.D., and William R. Duncan, M.D.

The Twenty-third Annual Meeting of the Western Orthopedic Association was held in Denver, Colorado, October 18 through October 22, 1959, under the Presidency of Dr. William F. Stanek. In addition to a program of excellent papers from the various chapters of the Western Orthopedic Association, a symposium on radio-active isotopes was included with discussions on "The Physical Properties" by Thad P. Sears, M.D., Chief of the Medical Service of the Veterans Administration Hospital, Denver, Colorado; "Radio-Active Isotopes in Medicine" by Robert W. Lackey, M.D., Radiologist, Presbyterian Hospital, Denver, Colorado; and "Radio-Active Isotopes in Industry" by P. W. Jacoe, A.B., Chief, Occupational Health Section, Colorado State Board of Health, Denver, Colorado.

The Resident-Training Program awards named in honor of the originator, Dr. Vernon P. Thompson, were given to the following essayists: First Prize (tied): Robert A. Dennison, M.D., Scottish Rite Hospital, Dallas, Texas, for "Analysis of 55 Consecutive Shoulder Arthrodeses", and Robert F. Mazzetti, M.D., University of California School of Medicine, San Francisco, California, for "Effect of Immobilization of the Knee on the Energy Expenditure During Walking". Third Prize: Warren A. Ross, M.D., Scott and White Memorial Hospital, Temple, Texas, for "Multiple Myeloma"; and Fourth Prize: John G. Mahaney, M.D., Shriners' Hospitals for Crippled Children, Salt Lake City, Utah, for "The Surgical Treatment of Club-foot Residuals".

Officers elected for 1960 were:

President-Elect: Marvin P. Knight, M.D., Dallas, Texas;
Vice President: F. Bruce Kimball, M.D., San Diego, California;
Secretary: Walter F. Carpenter, M.D., San Diego, California;
Treasurer-Historian: Walter Scott, M.D., Los Angeles, California.

Dr. Fraser Macpherson was installed as *President* for the coming year. The next Annual Meeting will be held in San Diego, California, October 23 through October 27, 1960.

The **1961 meeting** will be held at the **Statler-Hilton Hotel in Dallas, Texas,** October 17 through October 21. The **1962 meeting** will be held at the **Fairmont Hotel, San Francisco, California,** October 28 through November 1. The **1963 meeting** will be held in **Seattle, Washington.**

Summaries of the papers presented follow:

Radial Styloidectomy and Styloidectomy Plus Bone Graft in the Treatment of Old Ununited Carpal Scaphoid Fractures. Dr. Robert Mazet, Jr.[1], and Dr. Mason Hohl[2] presented eleven cases in which non-union of the carpal scaphoid was treated by styloidectomy alone and thirteen cases in which it was treated by styloidectomy and bone-grafting (Barnard and Stebbins operation). All patients were men from twenty-one to fifty-eight years of age.

In the group of patients treated by styloidectomy alone, the non-union had been present for from three to twenty-two years. The period of follow-up ranged from two to ten years. In this group of patients, a good result was a painless wrist with improved motion after operation; a fair result was lessening in subjective and objective disability, with satisfaction on the part of the patient; and a failure was either no improvement or increase of the disability. There were six failures, three fair results, and two good results. In four of the failures, subsequent wrist fusion was done; in the fifth, fusion was advised; and in the sixth, a Barnard-Stebbins operation was done. The styloid was cut back to the fracture line in four patients, and well back of the fracture line in seven; this did not seem to affect the result.

Among the thirteen patients who had styloidectomy and bone-grafting, there was one case each in which the lesion at the time of surgery had been present for one day, six days, five months, and thirty-five years, respectively. The majority had been present from between two and seven years. The period of follow-up ranged from one to twelve years. In this group of patients an excellent result was union and a painless wrist with little or no limitation of motion; a good result was union, occasional discomfort, and less than 30 per cent of limitation of motion; a fair result was union and pain on vigorous or prolonged use of the wrist, with 50 per cent of limitation of motion; and a failure was non-union, much pain, and marked restriction of motion. There were five excellent results, one good result, three fair results, and four failures. In this group of patients, as in the first group, cutting the styloid back to or beyond the fracture line appeared not to affect the result.

In twenty-four cases of non-union of the carpal scaphoid, the results in patients treated by styloidectomy and bone-grafting were considerably more encouraging than those treated by styloidectomy alone. Convalescence after the Barnard-Stebbins operation was considerably

1. Veterans Administration Hospital, Los Angeles 25, California.
2. 435 North Roxbury Drive, Beverly Hills, California.

longer, but the results seem to justify the longer immobilization. Neither the age of the patient, the age of the fracture, the presence of vacuolization of fracture fragments, nor the amount of radial styloid removed had any appreciable affect on the result. In both groups, patients in whom there was significant arthritic change had uniformly poor results.

Achilles Tenodesis for Paralytic Calcaneo-Cavus Foot. Dr. John T. Jacobs [3] said that paralytic calcaneocavus is disabling because: (1) The loss of gastrocnemius-soleus power allows the short flexors to contract, rotating the calcaneus into a more vertical position to produce a cavus deformity; (2) malposition of the calcaneus permits the peroneals and anterior tibial muscles, by their flexion of the fore part of the foot, to increase the cavus deformity; (3) the foot does not develop normally and becomes smaller than its mate; (4) associated genu recurvatum often develops; and (5) absence of push-off makes an awkward gait.

The undesirable action of the peroneus longus and anterior tibial muscles is corrected by detaching the tendons of these muscles near their insertions. With the foot in full equinus position, they are drawn through a transverse hole in the calcaneus and sutured to each other. The calcaneus deformity is corrected by section of the heel cord at the musculotendinous junction, splitting the tendon longitudinally, and drawing each half in opposite directions through a transverse hole in the tibia three or four inches above the ankle. Each half is sutured to its opposite after emerging from the tunnel through the bone. The foot is held in equinus position by a plaster cast for six weeks after operation.

This operation not only corrects the deformity, but improves the dynamic deforming factors of the muscle imbalance. It results in stability, improved gait, and growth of the foot at a relatively normal rate. It can be done on a patient of any age. It does not prohibit subsequent surgery if that becomes necessary.

In discussion, Dr. M. P. Knight [4] said that the operation described eliminates continued deforming action of the peroneus longus and anterior tibial muscles, stops dorsiflexion of the foot, and permits continued growth of the foot. It may also obviate necessity for later wedge osteotomy.

Surgery of the Forefoot in Rheumatoid Arthritis. Dr. Mack L. Clayton [5] said that the most common combination of deformities of the foot caused by rheumatoid arthritis is hallux valgus, bunions, depressed metatarsal arches, and cock-up toes, which may be subluxated or dislocated and rigid. Painful calluses under metatarsal heads and shoe pressure on the dorsum of the toes may be quite disabling.

Resection of the metatarsophalangeal joints with partial phalangectomy and removal of the metatarsal heads has proved most satisfactory in severe disabilities of this type. The operation is done through a transverse incision at the base of the toes on the dorsal surface. Ten toes may be done at one operation. The toes are straightened out and held in the desired new position by a compression dressing for two weeks. Patients can be out of bed in from five to seven days, and home in from one to two weeks. After operation, the patient wears an oxford type of walking shoe with metatarsal bar.

Twenty-five feet have been thus treated with gratifying cosmetic and functional results, both to patients and to surgeon. Dr. Clayton stressed the necessity for removal of enough bone for the correct relative alignment of the distal metatarsal stumps to avoid any single pressure area.

In discussion, Dr. J. R. Schwartzmann [6] stated that he has been employing resection of the metatarsal heads in severely crippled rheumatoid feet for some years with very satisfactory results. He prefers plantar incision. The discussant, however, did stress that rheumatoid arthritis is a generalized, progressive, and more or less continuing disease, involving both bone and joint as well as soft-tissue structures. He pointed out that the inflammatory changes in the primary disease are followed inevitably by traumatic changes in joints, which perpetuate the chain of symptoms and deformities.

Dr. Schwartzmann also said that surgical reconstruction of the type described by Dr. Clayton applied in a progressive disease becomes more or less palliative and may be part of a serial need for subsequent treatment and revision of affected joints in the patient with rheumatoid arthritis. Major objectives in surgical treatment of the rheumatoid foot are the relief of pain, improvement in smoothness of gait mechanics, and the relief of stress and strain on other related weight-bearing joints by such improvement. The discussant found end results entirely satisfactory if the proximal phalanges of the toes are left intact. Pain can be relieved and the deformity corrected by adequate extensive metatarsal-head resection.

Sciatic Scoliosis in the Child. Dr. J. C. Risser [7] and Dr. C. E. Workman [8] found that low-back pain with sciatic radiation producing muscle spasm and a list away from irritated nerve roots characterize sciatic scoliosis. It is uncommon in young children, usually appearing at about

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4. 2618 Welborn Street, Dallas 19, Texas.
5. 1855 Gaylord Street, Denver 6, Colorado.
6. 2415 East Adams, Tucson, Arizona.
7. 2627 East Washington Boulevard, Pasadena, California.
8. 1300 West 6th Street, San Pedro, California.

twelve or thirteen years of age, is more frequent in female patients, and indicates severe disease.

Continuing scoliosis in the child produces soft-tissue contractures on the concave side, asymmetrical growth of vertebrae, and fixed structural deformity. This is demonstrated by persistence of the curve in recumbency. The best therapy is fusion. In spondylolisthesis, the arch is removed and posterior bone grafts, obtained from both posterior iliac spines, are inserted between the fourth lumbar vertebra and the sacrum.

The authors reported two cases of sciatic scoliosis due to spondylolisthesis and one due to lumbosacral tuberculosis.

In a girl of eleven, treatment by back brace with thigh extension did not relieve either spasm or scoliosis. An increase of forward slip of the fifth lumbar vertebra on the first sacral vertebra was noted. Fusion was done a year later. One and a half years after operation there was no increase of curve and correction was maintained at the preoperative recumbency.

The spine of a fourteen-year-old girl with a similar lesion was fused. Four years later the curve had not increased and correction was held at the preoperative recumbency. Immobilization was maintained with an axilla-to-groin cast for three months.

Scoliosis developed in a boy whose fusion for tuberculosis was not sufficiently long. At follow-up ten years after extension of the fusion, the disease was quiescent and no increase of deformity had occurred.

The authors pointed out that spondylolisthesis may be incidental and not the cause of symptoms. In one child with lumbar scoliosis and an innocuous spondylolisthesis, fusion of the lumbar spine was enough to prevent increase of deformity.

New Concepts in Lower-Extremity Prosthetics. Dr. Cameron B. Hall [9] and Charles Hennessy, C.P.[10], said that the evolution of the rectangular shape of the present above-the-knee socket is based on sound anatomical and engineering principles. Strict conformation to the shape of the stump is not desirable. Much of the weight must be borne on the ischium and glutei, so the stump must be held back on the seat. Best function is obtained when the stump is slightly flexed and adducted. The adductors and flexors are then relaxed and can be somewhat compressed. All muscle groups must be permitted to function, and channels are provided for the purpose. Because the hip abductors lie above the socket their function is not impaired by the prosthesis. The anterosuperior wall of the socket is somewhat S-shaped to set the stump back on the ischial seat by applying equal pressure over Scarpa's triangle without inhibiting action of the sartorius, rectus femoris, and tensor fascia lata. The entire lateral wall furnishes support to the stump, permitting the foot to be brought under the body for a narrow walking brace and putting the abductors on slight tension, which increases their efficiency. Better function of the extensors is obtained in like manner by putting these on slight stretch. The medial wall does conform rather closely to the stump contour to keep the stump against the lateral wall.

Principles found effective in fitting the amputee have been utilized in the ischial weight-bearing brace. The quadrilateral socket shape, formed in leather, plastic, or wood, produces greater stability, increased comfort, and improved gait, as compared with the conventional shape of the ischial ring seat.

Chemical Osteosynthesis. Dr. Irving Redler [11] reported his experiences with ostamer in fifty operations performed on forty-one patients, seven of whom were children. The procedures in which it was used were: open reduction and internal fixation of fresh fracture; open reduction and fixation of pathological fracture; internal fixation of delayed union and non-union; osteotomy; arthrodesis; and filling of bone defects.

The author described some of the problems encountered in using ostamer. Postoperative immobilization was accomplished by plaster-of-Paris or by traction and maintained for from several days to several weeks. In a few instances, immobilization in plaster was continued for several months in an effort to obtain bone union. Weight-bearing or functional use was not permitted until wound healing had occurred and only then if there was clinical evidence of solid fixation.

The results of this study are evaluated on the basis of maintenance of fixation and development of bone union. At the end of eight months—the maximum follow-up period—nine procedures had resulted in bone healing, fifteen had definitely failed, and in twenty-six the results were undetermined. It was noted in the breakdown of end results that eight of eleven operations on the long bones of the upper extremity had caused healing by subperiosteal callus formation; the remaining three had produced solid fixation, but the bones were ununited. In contrast to the apparent high rate of healing following this procedure on the long bones of the upper extremity, only one of the eighteen operations on the long bones of the lower extremity had resulted in healing by callus formation, and the results of six of these eighteen procedures were undetermined at the time of evaluation. Eleven of the operations on the long bones of the lower extremity were known failures. Ostamer was used for fixation after nineteen arthrodeses; there were four failures at the

9. 153 South Lasky Drive, Beverly Hills, California.
10. Los Angeles, California.
11. 1539 Delachaise Street, New Orleans 15, Louisiana.

time of evaluation—two at the knee, one at the hip, and one at an interphalangeal joint. Among the remaining fifteen arthrodeses the fixation was still firm but there was no evidence of bone union at the time of evaluation.

Numerous complications were encountered: Breaking of the ostamer column at the site of bone fracture occurred in four instances, twice in the tibia and twice in the femoral neck. The column of ostamer material pulled away from the bone cavity in eleven instances, all of these being in the femur and tibia except for one which occurred after an attempted fusion of an interphalangeal joint of a finger. Wound infection and draining sinuses of varying degree of severity developed in thirteen patients at different postoperative times. In one patient postoperative drainage developed as late as four months after initial surgery. One failure of fixation after using ostamer for arthrodesis of the knee joint and for repair of an ununited fracture of the shaft of the same tibia resulted in amputation because of the extent of the infection and failure to obtain union. Removal of the ostamer was required in four patients to control infection and drainage, and the author anticipated it will be required in an additional four for similar reasons. He further anticipated that subsequent repair by bone-grafting will be necessary in the eight patients who require removal of the ostamer.

Microscopic sections taken from the ostamer mass from patients on whom reoperation was done showed no evidence of osteoblastic activity in the central portions of the ostamer as late as four months after operation. There was some degree of fibroblastic proliferation within the ostamer lacunae at the periphery of the mass at its point of contact with bone.

The author is of the opinion that at least three to five years' observation will be necessary to learn if in man ostamer is ultimately replaced by bone within a two-to-four month period as it seemed to be experimentally in dogs. He said that in the light of present knowledge, in the future his use of ostamer will be restricted to the treatment of pathological fractures and to unusual situations in which therapy by conventional methods is unsuitable. He further said that chemical osteosynthesis, because of its potential benefits, warrants continued careful and thorough investigations. Ostamer should be regarded as a prototype of future materials that will provide greater strength, easier handling, rapid replacement by bone, and will not cause local and systemic reaction. When such a material is found, its application in the field of bone surgery will be unlimited.

Refrigeration Treatment of Acute Osteomyelitis in Children. Dr. Robert Bingham [12] presented a follow-up study to a preliminary report made in 1947. The original study embraced the observations of ten cases of acute osteomyelitis treated by refrigeration therapy. In the twelve years since the first report, the author observed twelve additional cases. In the combined group of twenty-two patients, there have been no deaths and no ankylosis or destruction of a joint has occurred.

The treatment of acute hematogenous osteomyelitis can be improved with refrigeration therapy of the infected area. Refrigeration should be continued until all local signs and symptoms of pain, swelling, heat, and redness have subsided. Small lesions can be refrigerated with one or two ice caps kept in place for twenty-three of twenty-four hours. Larger lesions are treated with crushed ice placed over a wet towel and covered with rubber or plastic sheeting. The cold makes the patient more comfortable, reduces signs of systemic infection, reduces fever, relieves painful swelling, and limits both local and systemic spread of the infection. Refrigeration does not appear to interfere with natural resistance mechanisms which are mobilized to overcome the infection, nor does it inhibit the efficacy of antibiotics.

The length of hospital stay is shortened by about two-thirds with the therapy just described. Late and damaging sequelae, chronic infections, recurrent infections, sequestra formation, and subsequent deformities have been reduced by local cold therapy.

The effectiveness of refrigeration therapy combined with antibiotics in acute hematogenous osteomyelitis has been clinically demonstrated and these assumptions should be corroborated by further trials and experimental evidence to confirm the hypothesis that: (1) The rate of multiplication and reproduction of bacteria is inhibited by lowered temperatures; (2) Bacteria when chilled become more susceptible to attack by the immune mechanisms of the body; (3) Lowered temperatures reduce the output of bacterial toxins and metabolic substances, such as penicillinase, which tend to destroy the activity of penicillin; (4) Tissue metabolism and oxygen consumption are decreased with cold applications, thus reducing tissue necrosis, autolysis, and the formation of pus; (5) Pain is controlled by the use of cold therapy, reducing sympathetic vasospasm and improving deep circulation of the infected limb; and (6) Refrigeration of a limb may be continued indefinitely (a period of seventy-five days has been reported) with no detrimental effects in wound healing.

In discussion, Dr. R. E. Forbis [13] was in general agreement with the author's report and did not take issue with his theories and analyses. The discussant felt that the use of refrigeration therapy as an additional aid in treatment of infection, both generalized and localized, offers a new agency in the therapy of this problem in orthopaedic surgery. In addition, the discussant mentioned his own experience with relief of pain by refrigeration methods.

12. 3536 Tenth Street, Riverside, California.
13. 27 Medical Arts Square, Albuquerque, New Mexico.

Avulsion Fracture of Fibula: A Cause of Ankle Instability. Col. John J. Brennan [14] and Lt. Col. William F. Macdonald [15] said that chronic and recurrent instability of the ankle joint may result from small fractures of the lower part of the fibula that fail to unite. If the ununited fragments have the fibular collateral ligaments of the ankle attached to them, chronic instability of the ankle joint may occur. Such ankles have been treated operatively by freshening the site of non-union and reattaching the fragments of the ununited fibula to their normal position in the lateral malleolus.

Small avulsion fractures of the fibula at the ankle joint may result in instability of the ankle without associated ligamentous defect. A comparable pathological condition was present in all the patients reported by the authors; stability of the ankle joint was regained by surgical correction of the non-union of the avulsion fractures.

In discussion, Dr. Douglas D. Toffelmier [16], in general, confirmed the authors' observations. In the discussant's experience, detailed and definitive surgical treatment for these injuries in the acute stage results in a reduction of the incidence of non-union, as well as reduction in the duration of convalescence after trauma.

Role of the Degenerated Disc in Low-Back Syndrome. Dr. Arthur Holstein [17] and Dr. Gwilym B. Lewis [18] analyzed seventy-five consecutive patients with low-back syndrome who were treated surgically. They correlated symptoms, myelograms, and pathological specimens, and concluded that the disc syndrome is basically a degeneration. Histologically, the same basic pathological changes—including fibrillation, edema, and inflammatory reaction—are present, whether the disc tissue remains *in situ*, is extruded completely, or constitutes a bulging with direct nerve impingement. Alterations within the disc permit pain stimulation to occur. This stimulation takes place in the periphery of the disc area because the annulus fibrosus itself has no definite nerve endings within it. Part of the pain sensation of the disc area is contributed by the invasion of granulation tissue with its accompanying blood vessels. This granulation tissue grows into the degenerated disc as part of the healing reaction of this tissue and serves as a source of sensory nerve supply.

In addition, the rami communicantes and the sinuvertebral nerves at each level distribute sensory fibers to the facets, ligamentum flavum, and anterior and posterior longitudinal ligaments. These rami communicantes and sinuvertebral nerves constitute part of the afferant pathway to the spinal segment that corresponds to the dermatome supplied by the spinal nerve at this spinal level. Painful stimuli, mediated by the rami communicantes, the sinuvertebral nerves, and other nerves that supply the region of the degenerated disc and its related structures, may therefore produce referred pain of dermatome distribution, the pain noted in association with degenerated-disc lesions. A gross disc herniation with its definite neurological findings is only one phase of the total picture of disc degeneration.

Surgical treatment for degenerated-disc lesions is really one of denervation and the creation of space. The surgeon should be liberal in his laminectomy, for the more space he makes, the more complete is the denervation. Spine fusion in addition to the laminectomy in some instances reduces motion at all sites of pain stimulation, except when the pain is due to direct pressure on the nerve root itself.

In discussion, Dr. Robert L. Garrett [19] expressed the belief that the authors presented an important observation of the mechanism by which the degenerated disc serves as a source of pain in the back. The discussor presented further illustrative material to support this concept.

Exploding the Avascular Necrosis Theory in Hip Dysplasias and Legg-Calvé-Perthes' Syndrome. Dr. William A. Craig [20] and Dr. Warren G. Kramer [21] presented a well illustrated serial study of cases of congenital dislocation of the hip and Perthes' disease. They propounded the theory, supported by their illustrations and periodic observations, that necrosis of the femoral head in congenital dislocation of the hip and in Legg-Calvé-Perthes' disease is primarily a biomechanical pressure phenomenon rather than a vascular phenomenon, as is generally accepted at the present time. In dislocated hips, so-called necrosis does not occur prior to reduction unless the head is articulating firmly with the ilium. After gentle reduction by traction or splint with release of the focal pressure, the necrotic area within the femoral head recovers. The authors demonstrated by slides that necrotic changes do not occur within the femoral head while the hips are held in frog-leg position unless there is a history of difficult forced reduction, and, if necrosis occurs from forceful reduction, it will be localized to the part of the head under pressure and not generalized as in the avascular type. In three of the patients reviewed with dysplasia of the hip on one side and congenital dislocation on the other, equally pronounced changes in both hips

14. William Beaumont Army Hospital, El Paso, Texas.
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16. 426 17th Street, Oakland, California.
17. 3011 Telegraph Avenue, Berkeley, California.
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19. 1512 Napa Street, Vallejo, California.
20. 8540 La Entrada Avenue, Whittier, California.
21. 909 North Spadra Road, Fullerton, California.

developed after reduction of their dislocations. Dysplasia of the hip sets the stage for a Legg-Calvé-Perthes' syndrome.

The authors described their method of treatment and the follow-up observations, but said that the present report is only a preliminary one and not an end-result study. It is their hope to stimulate a reappraisal of the primary avascular theory, which breeds such a fatalistic attitude toward treatment of these conditions.

The primary cause of necrosis of the femoral head in the reduced congenitally dislocated hip in Legg-Calvé-Perthes' syndrome and in degenerative hip-joint disease is mechanical in origin. This explains the close similarity of the roentgenographic findings and clinical courses of these related diseases. Altering the mechanics by exercises, splinting, or surgery has produced good results in the treatment of all three conditions.

In discussion, Dr. Lawrence Noall [22] agreed that anteversion of the femoral neck and increased coxa valga cause abnormal pressure in the hip joint and observed that subtrochanteric osteotomy to improve the position of the elements of the hip joint results in a gradually improving appearance of the ossification of the femoral head. Skeletal traction in reducing hips is an aid in improving ossification of the head of the femur. If coxa valga is present, placing the femoral neck in more varus position operatively will produce more uniform contact between the femoral head and the acetabulum and relieve undue pressure on areas of the femoral head from the acetabular rim. A temporary increase in limp from varus positioning of the femoral neck tends with growth to decrease as a normal neck angle develops. Weight-bearing after reduction of the subluxation promotes ossification of the femoral head, and the use of an abduction splint is effective in promoting weight-bearing on the limb with the hip elements in proper relationship.

In five hips with Legg-Calvé-Perthes' syndrome opened surgically, the head of the femur faced somewhat forward in an anteverted position. Improvement in the healing of these hips was accomplished by wedging the anterosuperior acetabular margins down to fit the femoral head.

New Concepts Derived from Experience with Intervertebral-Body Fusion. Dr. Charles G. Hutter [23] studied fifty patients with lumbar spine fusion achieved by placing autogenous blocks of bone between two lumbar vertebrae. The author evaluated his experiences with this method of treatment and presented the basic concepts derived from this experience.

Dr. Hutter showed numerous slides of postoperative end results and discographic findings. In analyzing his experience with the procedure, he pointed out the importance of accurate localization of disc disease by discography and of hypotensive anesthesia during operation. There is complete relief of pain when a single offending disc space is fixed by intervertebral bone blocks since pain is the result of abnormal motion between the vertebral bodies, produced by the unstable disc.

The patient's satisfaction with this method of treatment has led the author to select this procedure as the method of choice for treating low-back pain, whether it is associated with sciatic pain or not.

In discussion, Dr. Leon Wiltse [24] reaffirmed that discograms are of definite value in the study of low-back disease and that it is a procedure which can be employed by orthopaedic surgeons in evaluating low-back pain. Fusion between the vertebral bodies is difficult to obtain, and, if not accompanied by a posterior element fusion, should be reserved for the unusual case or be performed on a semi-investigative basis only.

The Advantages of Lateral Onlay Distal Inset Tibial Bone Graft over Sliding Bone Graft for Non-Union Lower Third Tibia. Dr. J. Howard Varney [25] described a lateral onlay graft, with the distal portion set into the flare of the distal part of the lateral side of the tibia and fixed in place by screws inserted from the medial side of the distal part of the tibia for fractures in the distal third. The graft is removed from the upper crest of the tibia instead of using a sliding graft from the region of the fracture site.

The advantages of this method over the sliding graft are: (1) A larger graft may be applied; (2) Fixation is more secure since the holding screws go through both cortices of the tibia instead of just one, as in the sliding bone graft; (3) Insertion of the graft into the lower part of the tibia promotes prompt union because the bone graft is surrounded by host bone, where it fits snugly into a nest of cancellous bone; (4) On the lateral side the overlying muscle and tendon furnish a better vascular supply to the graft than is possible on the medial side, where just skin covers the bone; and (5) The incision avoids the poor skin and scarring, which are often present over the anterior lower third of the tibia. The approach in this case is by an incision between the fibula and tibia near the lateral tibial border.

Two cases of non-union of the distal part of the tibia treated successfully by this method were presented.

Balancing the Grip of the Injured Hand by Transposition of Digits. Dr. Robert E.

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25. 1801 28th Street, Bakersfield, California.

CARROLL [26] said that in reconstructing the injured hand, it should be remembered that three functional divisions of the hand should be restored to enable maximum use. First, the thumb, which is the highly mobile unit of prehensile ability. Because mobility of parts is important, there must also be an adequate space or web between the thumb and the opposing post for pinch or grip. The second unit of function in the hand is the firm post normally supplied by the index and long fingers. Because of minimum motion of the metacarpals of these fingers, these posts give strength to the grip. The third functional unit of the hand is the ring and little finger, which give modulation to the grip. Because of the mobility of their metacarpals, these digits move to adjust or modify the grip. If these three divisions are considered when reconstructing an injured hand, maximum function will result.

When a thumb has been removed, the index finger should be pollicized. This will give a mobile thumb and maintain a deep web for grasping and holding. If a stiff, reconstructed thumb is formed, its length should be adjusted so that it does not extend beyond the proximal quarter of the proximal phalanx of the index finger.

No digit should be moved to replace the index ray. Excellent pinch is obtained from the long finger and many normally use this digit. If less than full length of the proximal phalanx of the index finger remains, it is better to remove the entire ray by dividing it at the very base of the metacarpal.

The loss of the phalanges of the ring or long finger leaves a gap in the hand leading to marked angulation of the index finger at the metacarpophalangeal joint. If the index finger has enough length to be useful for function, it should be moved to the position of the long digit. In this way the wide gap between the thumb and its opposing post is maintained. The balance of power in the hand is not quite so well maintained when the fourth ray is moved to the position of the long digit.

Should portions of the ring finger that do not participate in the grasp remain, all of the finger that remains, including its metacarpal, should be removed. The metacarpal is best excised subperiosteally, and the tube closed thereafter. This will pull the metacarpal head of the little finger into the palm and close the gap. There is no reason to transpose the little finger into the position of the fourth ray.

In the little finger, functional length must be present or the stump must be amputated to the base of the metacarpal. Transposition of a digit to replace the little finger does not seem necessary.

Balancing the grip in the injured hand depends on maintaining a representative from each of the three units of function. Saving a metacarpal to keep a broad palm is not necessary. Digits can easily be transposed, with resultant full power and range.

In discussion, DR. DONALD R. PRATT [27] considered the strength of grip as one of the important factors in evaluating disability of the hand. The loss of any of the finger segments, the intrinsic stiffness in the finger joints, the efficiency of the gliding mechanisms of the tendons in the fingers, palm, and forearm, and any atrophy of the muscles of the forearm influence the strength of grip.

The loss of the distal portion of a central metacarpal upsets the mechanics of the metacarpal arch of the hand. Improvement in the appearance, and, to some degree, in the function of the hand when the third metacarpal head is missing can be afforded by excising the remaining middle portion of the third metacarpal with the associated cicatrix, and moving the index finger over onto the remaining proximal portion of the metacarpal of the long finger. It should be remembered, however, that any transplanted normal digit loses some function in its new position. Preservation of the intact third metacarpal, when the long finger is amputated through the proximal phalanx at any level or through the metacarpal phalangeal joint, has been found to offer maximum function. Moving the index finger over onto the third metacarpal would lessen the strength of the grip.

Effecting transposition of the index finger by transverse osteotomies through the second and third metacarpals affords early healing and ease of maintenance of the transposed position, obviates interference with function of the wrist extensor tendons, and avoids the subsequent development of arthritis of the metacarpocarpal joint. Only in selected cases where cicatrix is extensive in the center of the hand around the partially amputated third metacarpal would improvement of function be expected to follow surgical transposition of the index finger. Moving the index finger to the third metacarpal axis does not deepen, widen, or improve the thumb cleft because the thumb ray moves over with the transposed index ray.

Transposing a digit is a major surgical undertaking and should not be considered lightly. It should be used in very selected cases and it should be clearly kept in the mind that the prognosis for improvement in function, even in grip, should be guarded.

Facial Paralysis Following Poliomyelitis. DR. CHARLES L. LOWMAN [28] reported from the records of the Orthopaedic Hospital Clinic in Los Angeles forty-one cases of facial paralysis after poliomyelitis and an additional twelve cases from his private practice.

The incidence of facial paralysis after poliomyelitis, although usually considered infrequent, is not at all rare. Reports on facial paralysis in the literature, for the most part, have dealt with

26. 180 Fort Washington Avenue, New York 32, N. Y.
27. 516 Sutter Street, San Francisco 2, California.
28. 2417 South Hope Street, Los Angeles 7, California.

Bell's palsy, a traumatic or infectious form of lower motor neuron involvement, which is treated by the use of a mouth hook and, usually, galvanism with massage. The author prefers to use the mouth hook of Robert Jones.

The facial splint, recently described by McKearly, has been known for some years. It consists of a flexible hook made of aluminum covered with rubber, celluloid, or plastic. The material is bent into a hook, one-half of an inch long, and has a shank one and one-half inches long. A rubber band fastened through to a small hole in the shank is passed around the ear on the affected side and adjusted to take up the slack in the affected cheek muscles, and, more particularly, to prevent the strong muscles of the opposite side from pulling the mouth to that side.

In evaluating muscle paralysis the author emphasized the importance of graphic recording of muscle strength in preference to the use of Lovett's or Kendall's percentage scale. He also stressed the psychomotor aspect of muscle function, pointing out that as organs of expression our muscles are one of our chief means of communication with our environment. Most emotions are expressed by a concomitant motor action. This is especially evident in the head, shoulder, arm, and hand regions.

Faults in the muscle strength and balance of the shoulder girdle and neck not only cause disability due to muscle weakness but also provoke postural strain. In order to focus the eyes and concentrate on a specific action, the head must be held still or be stabilized by muscles that extend from the head and neck to the shoulder girdle. As the hands generally are used at the same time that the eyes are focused for some activity there must be coordinated action of all the hand and arm muscles, which have the same base of support—the shoulder girdle. The shoulder girdle is supported by the rhomboids and the lower trapezii, which extend from the scapulae to the spine. A still further chain of stabilizing force must extend to the seat in sitting or to the floor in standing.

Dr. Lowman called attention to these factors to emphasize that treatment of facial paralysis involves more than just the facial muscles. Avoidance of fatigue or strain is important since movements of the finer muscles of coordination cause fatigue more readily than do those of heavier, coarse-fibered muscles.

In the treatment of facial paralysis hot packs, used at the general hospital in the acute stage of the disease, are usually continued on transfer to the orthopaedic hospital. Frequently, at about this time, the use of a mouth hook on the affected side is begun to prevent stretching of the weak muscles by action of the stronger opponents. In the chronic stage, packs are discontinued and electrotherapy, massage, and muscle re-education are started in addition to the use of a mouth hook. These are continued for two to three years. During this time the child is encouraged to register emotions, such as anger, happiness, fear, and sadness, with appropriate facial expressions. He scowls, smiles, is surprised (wide-eyed), grieves, shows teeth, wrinkles nose (like bunny), and widens the nostrils (smelling something unpleasant). Patients profit by this training in emotional expression and may establish motor patterns valuable for later years. In practicing these expressions, the patient is seated before a mirror with the therapist standing behind him and with no one else in the room.

In the plastic correction of facial paralysis by surgical means, Dr. Lowman listed the following procedures as having been used: (1) quadrilateral suture; (2) excision of redundant skin and subcutaneous tissue on the affected side in the laugh-line or from the forehead to raise sagging eyebrows; (3) "face lift" on the affected side; (4) external canthoplasty of the interpalpebral fissure on the affected side; and (5) deliberate interruption of branches of the facial nerve on the uninvolved side to prevent overaction of the muscles of the forehead and upper or lower lip.

In another technique fascial strips are passed from the lower cheek, the corner of the mouth, and the corner of the nose up to points of attachment on the temporal fascia. The tension of these strips is adjusted to restore facial symmetry.

The Diplegia of Prematurity. Dr. William R. Duncan [29] reviewed the syndrome of diplegia of prematurity, as reported previously in the literature, and analyzed thirty-five cases of spastic diplegia occurring in premature infants whose birth weight was under five pounds. He compared these infants with a control group in whom the birth weight was over five pounds. The results of the studies suggested that the diplegia associated with prematurity is a separate and distinct entity characterized by diplegia, normal mentality, and internal squint. The author also reviewed the pathological and etiological concepts of the disease and said that the diplegia associated with prematurity is probably due to an etiological process occurring as early as the fourth month of pregnancy.

This syndrome was first described in 1894 by the French neurologist, Brissaud. The term *diplegia* as used here implies a symmetrical spastic paralysis of the lower extremities with lesser involvement of the upper extremities.

In the cases presented by Dr. Duncan the incidence of spastic diplegia was high in infants under five pounds, whereas there was a completely different pattern of distribution in those over five pounds. Spastic diplegia is by far the most common type of involvement seen in the premature child. Most of these children are born between the sixth and seventh month of pregnancy with a mean birth weight of from three to four pounds. Very few of the infants are born later than the

29. 1607 Medical-Dental Building, Seattle 1, Washington.

seventh month of pregnancy. In studying the intelligence of these infants, those under five pounds showed a higher intelligence on the average than those over five pounds and actually give a boost to the intelligence of the general population of the cerebral-palsied child.

There was an internal squint in 71 per cent of the diplegics born weighing under five pounds as compared with 28 per cent in the diplegics born weighing over five pounds. The over-all incidence of internal squint in the general population of cerebral-palsied children is 25 per cent. The incidence of convulsions in the premature diplegics was only 17 per cent, whereas the incidence in all the cases studied was 51 per cent.

In discussion, Dr. George W. Cottrell [30] said that diplegia of prematurity is not a distinct entity; prematurity and cerebral palsy are parallel manifestations of some gestational abnormality causing both the premature birth and the disturbance of fetal neurons. There may well be an as yet undiscovered single cause of this symmetrical spastic syndrome analogous to the Rh sensitivity now recognized as the cause of kernicterus.

A New Femoral Nail Plate. Dr. Christopher A. Mason [31] presented a new femoral nail plate, a mechanical refinement of the principles delineated in 1914 by Dr. Merrill Preston, who designed and used the forerunner of all nail plates for fixation of trochanteric fractures.

The author developed this nail in an effort to solve two problems: (1) weakness at the angle of the nail plate, the point of greatest strain; and (2) severe weakening of the femur at the point of entrance, when any attempt is made to bolster the strength of the device at this point.

Dr. Mason's nail can be driven through a simple vertical slot through the lateral trochanteric area of the shaft. Other benefits of the nail are: (1) increased strength of the plate portion of the nail because of the quartering edgewise position of the plate portion, with respect to varus strain; (2) minimum protrusion beyond the lateral cortex of the femur; and (3) no particular inserter or extractor is required.

This nail has been used in over twenty-five fractures with favorable results.

Congenital Dislocation of the Radial Head. Dr. Kermit W. Fox [32] and Dr. Lawrence L. Griffin [33] discussed congenital dislocation of the radial head from the standpoint of etiology, clinical features, roentgenographic findings, pathology, diagnosis, and treatment.

Certain prevailing characteristics of the disease make it possible to differentiate a fresh traumatic dislocation from a congenital one. The roentgenographic findings are: the radial head is dislocated and underdeveloped; the proximal end of the head is flat or dome-shaped, instead of normally cupped; and the radial shaft is somewhat more slender and appears longer than normal when it is compared with the corresponding ulna. In addition, the capitulum humeri is underdeveloped.

Other findings that suggest a congenital rather than a traumatic dislocation are: existence of other congenital anomalies; bilateral occurrence of the dislocation; and familial occurrence. However, it may be impossible to differentiate definitely an old traumatic dislocation that occurred during infancy from a congenital one. Despite the characteristics mentioned, the need for differentiating is more academic than practical. Treatment usually consists in resection of the radial head. The chief indications for treatment are: undue dysfunction from limitation of pronation and supination of the forearm, or, occasionally, limitation of flexion or extension of the elbow; and (2) pain.

In discussion, Dr. R. G. Lambert [34] reported the findings in three cases he saw, two of which were in sisters.

Presidential Address. Dr. William F. Stanek [35] delivered the Presidential Address, which was, in brief: "Our membership is drawn from a large and extremely diversified area. We have one thing in common. We all 'think Western', and tend to turn over thoughts more each year to the Western rather than to the Eastern centers of culture. . . .

"The unique chapter organization of the Western is one of its greatest assets. It is important today and has potentialities for even greater influence in Western Orthopedics than it now exercises. The chapter organization permits a discussion of local and general orthopedic problems at the proper level. It can be used as a two-way communication system, both to transmit ideas of general interest to the local groups and to insure that local problems, wishes, and (more important) ideas and presentations are not lost to the parent organization. I believe it should be understood by everyone of us, by the presidents of the local chapters and by every member of the chapter, that membership in the Western Orthopedic Association is not gained simply by qualifications of training and of time in practice. Membership should be a guarantee to all of us that a man is not only qualified according to the book, but that he represents an individual practicing medicine in a way that is ethically acceptable to his fellows. The local chapter is the only place to judge those qualified by these standards.

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31. 1401 South Hope Street, Los Angeles 15, California.
32. 1010 West 19th Street, Austin 1, Texas.
33. 1010 West 19th Street, Austin 1, Texas.
34. 2554 4th Avenue, San Diego 3, California.
35. 1745 Race Street, Denver 6, Colorado.

"The chapter organization has a further value. It prevents domination of the Western Orthopedic Association by any particular group of orthopedists or by any type of orthopedist. As the spotlight falls on first one and then another of the chapters in the annual meetings, we are all given a chance to observe new talent and to see which of our members we would like to have representing us in other organizations.

"This annual meeting represents another essential part of the Western Orthopedic Association. The meetings are now of sufficient size and sufficiently well attended that orthopedists are presenting their 'show piece papers' at these meetings. Our attendance, our enthusiasm and the efforts of the editorial committee will increase the desire of our members to participate in the meetings. One of our present major efforts is to secure publication of all of our papers in one journal so that we may have a permanent record of our meeting and, in another way, demonstrate our national importance. . . .

"Standards of the membership of this organization must be continually revised and elevated. There has, over the past few years, been an undercurrent of comment that The American Academy of Orthopaedic Surgery has grown so large and so unwieldy that its breakup into regional meetings must be considered. While this is simply a remote possibility, it is worthy of our consideration. Should such an event occur, this organization must be in a position to decide the course it will take. There would be a grave question as to whether annual meetings of two such important bodies could be carried in this area without one of them suffering. If there should be any thought of combining a regional meeting of a national organization with that of the Western Orthopedic Association, the qualifications of membership in this Association must be as high or higher than those of the other partner. This means that men entering the Western Orthopedic Association from this time on as associate members can no longer expect to continue indefinitely on such status. . . .

"The expansion of the Western Orthopedic Association in terms of general orthopedic influence and in terms of the training of young orthopedic surgeons in the western area must be considered. Our farthest outpost chapter is in Honolulu. Westward are Australia, the Philippines, Japan, and India. May I suggest, augmenting Dr. Davis' report, that consideration be given to the inviting of outstanding orthopedic surgeons from these areas to our meetings thus spreading our influence and bringing new ideas to our members. . . .

"We have a definite obligation to further the training of young orthopedic surgeons in the western area. It is merely a question of how we go about it and how much money we wish to make available for such a program. . . .

"Is it practical to create traveling fellowships which would permit our residents to have a broader view of orthopedics in the western area? Is it practical to create fellowships under which the study of special problems of interest to our members can be undertaken by outstanding residents? Is it practical to send one of our best residents on a tour of the medical centers of Europe . . . ?

"In Colorado, we have our high and shining mountains. When Pike first saw the peak that is named after him, he felt that it could not be scaled. While most of us merely sit and gaze at the heights, there is always someone to climb to the top, to admire the view, and to obtain an inner satisfaction from his success. An organization, too, needs its shining mountain, considered by some impossible to conquer. I wonder if the Western, this year, has not seen such a peak. Tentatively, it has already been named 'Chair in Orthopedic Surgery in a Far Eastern University'. If what we have vaguely glimpsed is a high peak of endeavor and not merely a mirage, I am certain that while some will merely stand and say 'It can't be done', we will have enough to break trail, others to carry equipment and establish base camps, and somewhere in our number a few intrepid souls to reach the top and plant our flag."

Primary Cause of the Lumbosacral Disc Syndrome. Dr. Roger Anderson [36] and Dr. Ivan K. Loughlen [37] believe that the primary cause of the lumbosacral disc syndrome is, simply, joint malfunction. Their conclusion is based on their experience with 600 private patients operated on since 1947 in whom over 2,000 diarthrodial joints were examined, after having been fully exposed and then arthrodesed.

In discussion, Dr. John E. Stewart [38] suggested that the authors try to correlate their vast clinical experience with the symptomatology, particularly with respect to the joint disruptions they described. This would be a valuable contribution since it encompasses the experience of operation on 2,000 joints.

Lesions and Uses of the Upper Fibula. Dr. Robert A. Murray [39] and Dr. Hanes H. Brindley [40] reported that the proximal two-thirds of the fibula may be removed without residual disability to the extremity. Indications for resection of all or part of the proximal part of the

36. 509 Olive Way, Seattle 1, Washington.
37. 1319 Medical-Dental Building, Seattle 1, Washington.
38. 1120 Cherry Street, Seattle 4, Washington.
39. Scott and White Clinic, Temple, Texas.
40. 1312 N. Seventh Street, Temple, Texas.

fibula are: benign tumors of the fibula; resectable, malignant tumors; osteomyelitis; short amputation stumps with a long fibula; painful, ununited fracture in the middle or upper third of the fibula; for exposure of an arteriovenous fistula; to gain length in peroneal nerve repair; symptomatic dislocation of the proximal tibiofibular joint; to gain exposure of the posterolateral area of the tibial plateau; ununited tibial fractures with an intact fibula; arrested proximal fibular epiphysis; and as a bone graft. The fibula is resected through the exposure of Henry, leaving the periosteum, whenever possible, particularly in children.

The only major complication was a valgus deformity of the ankle due to shortening of the fibula after removal of a tumor in the proximal end of the fibula of a child six years of age. The upper fibular epiphysis had closed prematurely and the lower part of the fibula had been drawn upward away from the ankle. Improvement followed resection of the proximal epiphysis and a portion of the shaft.

The special merits of the fibula as a replacement graft for long-bone defects are its size, strength, and certainty of union, as well as the absence of complications related to the donor area. The proximal end of the fibula is particularly well adapted to replace the proximal end of the humerus and the distal end of the radius. When substantial lengths of the fibula are used in long-bone-grafting, fatigue fracture of the graft is certain to occur, usually about the sixth month after operation. The authors stressed the importance of using an intramedullary nail to prevent disintegration of the reconstruction if fatigue fracture occurs. The nail will provide support until complete revascularization and replacement of the graft bone have occurred. The ability of the transplanted fibula to hypertrophy and to adapt to its new environment over a period of years was emphasized.

Experiences in the Application of Homogenous and Heterologous Bone-Grafting and in the Use of Certain Types of Internal Fixation for Vertebral Body Fusion in the Lower Lumbar Spine. DR. PAUL H. HARMON [41] found that in addition to routine orthopaedic and neurological examinations, the following diagnostic maneuvers were useful in the diagnosis of lumbar-disc lesions: (1) lateral roentgenograms in flexion and extension; (2) oblique roentgenographic motion studies of apophyseal joint behavior (after paravertebral local anesthesia for elimination of reflex muscle spasm); (3) pantopaque myelography; and (4) saline-solution injection of the disc at operation to determine the volume of fluid that can be injected into the disc. In a series of 140 cases, the myelogram was found to be the least informative and accurate of the four tests. The findings obtained by saline-solution injection proved to be the most reliable.

Experience with 300 patients treated by anterior extraperitoneal-disc excision and vertebral-body fusion has convinced the author of the safety and efficacy of this procedure. The absence of subsequent perineural scarring, the ability to remove completely all sequestrated disc material, as well as the ease of spine fusion, justify the anterior approach. Compact bone, either autogenous or heterologous (calf bone), sandwiched between pieces of cancellous bone proved to be the most successful interbody graft, resulting in 93 per cent excellent and good results.

In certain selected patients, a Vitallium spheroid was inserted in the interbody space after partial disc excision.

In discussion, DR. HARRY C. HUGHES [42], with personal experience of fifty-two cases, agreed that the removal of discs by this approach is as satisfactory as by the posterior approach, but expressed disappointment with the high frequency of failure of fusion. The incidence of failure of anterior fusion, in his experience, has been as great as in posterior fusion.

Spondylolisthesis. Report of Two Unusual and Informative Cases. DR. LEWIS COZEN [43] presented two case reports that indicated that spondylolisthesis is a developmental defect of the spine not present at birth. In both patients roentgenograms of the lumbar spine made early in childhood showed an intact neural arch, yet later roentgenograms showed the typical appearance of spondylolisthesis.

Several theories of the etiology of spondylolisthesis were reviewed. The author favored the concept that the defect in the neural arch is an unrepaired stress fracture.

Analysis of 55 Consecutive Shoulder Arthrodeses. DR. ROBERT A. DENNISON [44] reported on a follow-up study (from six months to thirty-five years) of fifty-five operations for arthrodesis of the shoulder, and included a detailed evaluation of twenty-five patients. He suggested that shoulder arthrodesis is a very satisfactory procedure in the treatment of deltoid-muscle paralysis if certain basic requirements are met. For optimum results, the patient should have: a functioning trapezius of fair-plus strength or better; a functioning elbow, forearm, and hand; and, preferably, a functional serratus anterior muscle.

Fusion occurred most promptly when an intra and extracapsular procedure with rigid internal fixation and spica immobilization were employed. Positioning of the shoulder during the healing

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44. Texas Scottish Rite Hospital for Crippled Children, Dallas 19, Texas.

period was in line with the recommendations of the Research Committee of The American Orthopaedic Association—from 45 to 55 degrees of abduction and from 15 to 25 degrees of flexion of the arm, except in patients with a poor serratus anterior muscle. In these a position of only 30 degrees of abduction and from 10 to 15 degrees of flexion was used. A position of from 25 to 30 degrees of internal rotation is critical if the patient is to be able to zip his trousers and button his shirt, as well as comb his hair.

Twenty per cent of the results were unsatisfactory owing to failure of the arthrodesis; failure of the patients' muscles to meet the essential requirements of a functional shoulder girdle, a functional distal part of the arm, or both; and malposition of the arthrodesis, which limited the potential functional ability.

From the patient's appraisal alone, twenty-four of the twenty-five patients examined felt that the operation had been successful in restoring function to a useless shoulder.

The Surgical Treatment of Club-Foot Residuals. Dr. John G. Mahaney [45] reviewed nineteen recurrent club-foot deformities of fifteen patients, from twenty months to eight years of age, and emphasized the importance of systematic operative correction of the hind and fore part of the foot and of tibial deformity. The use of heel-cord lengthening, posterior capsulotomy, the Brockman procedure, capsulotomy of the tarsometatarsal joints (Heyman), rotation osteotomy of the tibia, transplantation of the posterior tibial tendon to the lateral border of the foot, and transplantation of the extensor hallucis longus to the dorsum of the foot were illustrated in various combinations.

The author stressed the importance of early correction of all components of the club foot to prevent late osseous and articular deformity.

Multiple Myeloma. Dr. Warren A. Ross [46] said that at the Scott and White Clinic from April 30, 1930, to May 1, 1958, multiple myeloma was diagnosed in eighty-five patients, representing 73 per cent of all primary, malignant tumors of bone seen during that period. The diagnosis was established by finding typical myeloma cells in the bone marrow of each patient. The most frequent symptom was pain in the back, with twenty-two of the patients manifesting symptoms compatible with a herniated intervertebral disc. Multiple osteolytic lesions were demonstrated in forty-nine patients. Significant laboratory findings were abnormal serum protein, albuminuria, elevated sedimentation rate, and anemia. Filter-paper electrophoresis of the patient's serum and urine proved a useful diagnostic test.

Elixir of urethan, adrenocorticotropic hormones or related steroids, androgens, and other supportive measures were used to relieve symptoms and to improve the general status of the patient.

Twenty-five patients had pathological fractures, the majority of which were vertebral, rib, and clavicular.

Nine patients (11 per cent) have survived for an average of forty-eight months, and one patient has survived twelve years.

Effect of Immobilization of the Knee on Energy Expenditure During Walking. Dr. Robert F. Mazzetti [47] recorded energy expenditure, as determined by oxygen consumption, in: eight normal subjects with the right knee immobilized by long leg cylinders at angles of 180 degrees, 165 degrees, 150 degrees, and 135 degrees, respectively; five normal subjects wearing a weight equivalent to that of the cast, but without any restriction of joint motion; five normal subjects wearing a five-centimeter (two inches) foot lift in conjunction with immobilization of the ipsilateral knee at 135 degrees of flexion; and six patients with operatively fused knees.

Results indicated that immobilization of the knee in normal patients produced a consistent elevation of energy expenditure during walking, most marked in the subject whose knee was immobilized at 135 degrees. In three patients with the knees operatively fused between 160 degrees and 180 degrees, there was no significant increase in energy expenditure. The shortening of an extremity resulting from flexion of the knee appeared to have little effect on energy expenditure during walking.

The addition of weights to an extremity to approximate the weight of a cast, but without restriction of joint motion, produced energy-consumption values above normal, but below those obtained with the knee immobilized.

Tendon Transference for Quadriceps Paralysis: A New Method of Using the External Oblique Muscle or the Illiopsoas as Motor Power for the Extensor Mechanism of the Knee. Dr. Paul A. Pemberton [48] said that because quadriceps paralysis is a severe disability, other thigh muscles, if available, can be transplanted to increase extensor power of the knee. If there are none, an awkward gait results and a toe-to-groin brace may be necessary.

45. Shriners' Hospitals for Crippled Children, Salt Lake City, Utah.
46. Scott and White Memorial Hospital, Temple, Texas.
47. University of California School of Medicine, San Francisco, California.
48. 220 Boston Building, Salt Lake City 11, Utah.

The obliquus externus abdominis has been used as a stabilizer of the hip in paralysis of the gluteus medius. The author attached the lower end of the obliquus externus abdominis to the patella, using the iliotibial band as an intermediary.

Active hip extension is a prerequisite to this surgery.

An incision is made just above Poupart's ligament and the iliac crest from the mid-line to the mid-axillary line. Through this, the lower end (insertion) of the obliquus externus abdominis is detached. The cut medial and lateral borders of the muscle are turned under to form a cone-shaped belly with a tonguelike tendon distal to it.

A long, lateral thigh incision exposes the iliotibial band throughout its length. Its attachments at the upper and distal ends are severed, but its anterior attachment is not disturbed. It is turned forward onto the anterolateral surface of the thigh.

The tendinous portion of the obliquus externus abdominis is brought subcutaneously, medial to the anterosuperior spine, and the upper end of the iliotibial band is wrapped around it and sutured to it. The lower end of the band is sutured to the front of the patella with the knee extended and the hip flexed to 45 degrees. A hip spica, applied with the extremity in this position, is worn by the patient for six weeks.

Eighteen such transfers have been done; seventeen have been helpful. The results of this procedure have been a greater stability in standing and walking and a feeling of greater safety on the part of the patient. Many have been able to discard their toe-to-groin brace.

The author said that he has transferred the iliopsoas into the patella through the intervening iliotibial band, and he thinks this may be a still better operation than the one described.

In discussion, Dr. Jacquelin Perry [49] said that the strength of the obliquus externus abdominis as a knee extensor is not great, but is enough to be quite helpful. Good abductors are necessary for its success. The quadriceps does most of its work during mid-stance when the knee is partly flexed. She questioned the necessity and desirability of leaving the anterior attachment of the iliotibial band.

Pigmented Villonodular Synovitis with Bony Invasion: A Report of Six Cases. Dr. Paul E. McMaster [50] said that pigmented villonodular synovitis, tenosynovitis, and bursitis are not uncommon and erosion and invasion of the bones of the hands and feet by tendon-sheath lesions are known to occur. But, he added, bone invasion by intra-articular synovial lesions is not well known; to his knowledge, none of these bone lesions in the knee have been reported.

The author reviewed the pathology, clinical course, physical and roentgenographic findings, and therapy of this condition. The symptoms and signs are principally due to synovial hypertrophy. He also reviewed twelve previously reported cases of bone involvement—eight of the hip, three of the elbow, and one of the wrist.

Extension into bone is by erosion through the cartilage and cortex at the chondro-osseous junction. The hiatus is small and the lesion expands within the medullary cavity. No significant productive reaction is elicited, so the involved area presents a vacuolated appearance on the roentgenogram. Opposing bones of the joint may be involved.

Dr. McMaster presented three cases of involvement of the bone of the hip joint and three of the knee joint, all proved by microscopic examination of the tissue.

Operative treatment is advocated, followed by x-ray therapy when there is doubt whether complete excision of all involved tissue was accomplished.

In discussion, Dr. Carl Anderson [51] said that contrary to the experience of Dr. McMaster, sclerosis may occur at the margin of the bone lesion, and calcification may be seen within the area. Pigmented synovitis invading the bone is invariably of long duration. He found no patients who had had symptoms for less than two years.

Closed Reduction Treatment of Tibial Condylar Fractures. Dr. Frederic W. Ilfeld [5] and Dr. Mason Hohl [3] said that Dr. Ilfeld has been using closed reduction and traction in the treatment of tibial condylar fractures for sixteen years, but does not use it when there is a central depression.

The technique of the operation is as follows: The patient is placed on a fracture table in a supine position. A Kirschner wire is passed through the calcaneus or the lower part of the tibia and from fifty to eighty pounds of traction is applied. The joint is aspirated. Sheet wadding and an Esmarch bandage are applied from well above the patella to below the tibial tubercle. A padded metal plate is placed against the condyle to be reduced. This is struck sharply with a mallet to replace the fragment. Due care is taken not to damage the peroneal nerve. After the depressed fragment has been elevated, a Böhler or C clamp is used to impact the fragments and restore the anatomy of the condyle. The procedure is done under portable roentgenographic visualization.

All constriction around the knee is removed. From fifteen to twenty-five pounds of traction

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is maintained while the patient's leg is placed in suspension on a Thomas splint with a Pearson attachment. The knee is kept at 180 degrees initially and this amount of skeletal traction is maintained for two weeks. The weight is then gradually reduced.

Quadriceps exercises are started at once. After a week, passive knee flexion, in traction, is commenced. Traction must be maintained for from four to six weeks. A bivalved plaster cast is then applied, but is removed during exercise periods. When the knee is comfortable out of plaster and the fracture is stable, the shell is discarded. Weight-bearing is not permitted for at least three months.

The results in fourteen patients were uniformly good.

Most tibial condylar fractures can be treated by this method. When the displaced fragment cannot be manipulated into place, open surgery may be done. Emphasis is placed on early knee motion in traction and on quadriceps exercises.

Pseudo-Arthrosis of Fracture of the Olecranon in Childhood (Patella Cubiti). Surgical Repair. Dr. Darrell G. Leavitt [53] reported the case of a Chinese man, thirty-two years old, who was seen in 1952 after contusion of his right forearm with subsequent weakness of the right elbow. He had injured the elbow in early childhood, but had had no symptoms prior to the presenting contusion. On examination there was weakness of elbow extension with triceps atrophy and crepitus in the region of the olecranon. Roentgenograms showed what was interpreted as an ununited displaced fracture of the olecranon. The olecranon epiphysis healed to form a patella cubiti.

Operative repair with screw fixation and lengthening of the triceps tendon was done. Five and one-half years after surgery, there was full range of elbow motion and forearm rotation. The circumference of the arms and forearms was equal. Roentgenograms showed union of the fragments.

In discussion, Dr. Dorsey K. Barnes [54] said that a case in which bone integrity of the olecranon was interrupted has been presented. The diagnosis could be old fracture with non-union or persistence of olecranon epiphysis (sometimes termed patella cubiti). In the absence of any other stigmata of arrested development, the first diagnosis is probably correct.

The Physical Background for the Understanding of Radioisotopes. Dr. Thad P. Sears [55] said that radioisotopes are becoming increasingly important to industry, research, and medicine. This is because of a quality they possess—radioactivity. A radioactive form for every element in the periodic table is now known.

Radioactivity is a form of kinetic energy created within an atom and transmitted outward in the form of waves or of moving particles at high velocity. Freeing of this energy may be instigated by the application of externally added energy, which renders the atom unstable, or the atom may have inherent instability from the beginning. The process of freeing this energy is known as radioactive decay and the rate of decay varies with each isotope.

Several types of radiation are emitted. We are principally concerned with alpha, beta, and gamma radiation and x-rays.

Matter consists essentially of electrons, protons, and neutrons. The electrons are disposed in elliptical orbits around the central nucleus of an atom. Protons, which carry a positive electric charge, and neutrons, with a neutral electric charge, are found within the nucleus. The chemical nature of an element depends on the number of protons in its nucleus. The simplest element is hydrogen. The nucleus of hydrogen contains one proton. From that point upward, one proton at a time is added. With each increment of one, the elements progress upward through the periodic table from hydrogen to helium, lithium, beryllium, and on upward to the level of uranium with ninety-two protons. For each positively charged proton in the nucleus of an atom, there will be one negatively charged electron in the orbital shells. This arrangement is necessary to preserve the electric neutrality of the total atom.

The atomic number of an element is equal to the sum of its protons. The sum of the protons and neutrons is ordinarily referred to as the atomic weight of an element. Actually, this should be called atomic mass or mass number.

The application of radioisotopes to research and medicine depends on the fact that, whereas every atom of the same element contains the same number of protons, the number of neutrons may vary within a rather wide range. This circumstance provides the definition of radioisotopes. Radioisotopes are defined as elements having the same atomic number but different atomic weights. Taking carbon, for example, the following forms can be defined:

$^{11}_{6}C$	$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$

The chemical and physiological reaction to a given isotope within the body depends entirely on the chemical nature of the element. This point is determined by the number of protons. Any isotope of the same element can therefore be utilized since all the isotopes of the same element will

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55. Veterans Administration Hospital, Denver 20, Colorado.

display the same chemical and physiological behavior. Thus, the radioactive form of an isotope may be introduced into the body, after which it can be instrumentally traced by reason of its radioactivity. Thus an atom, a cell, or a tissue is tagged. If there be specific uptake of an isotope by a particular organ, tissue damage may follow the administration of a radioactive isotope. This is helpful in treating some types of malignant growths.

Radio-Active Isotopes in Medicine. DR. ROBERT W. LACKEY [56] discussed areas in which radioisotopes have proved useful in medicine. These included: therapy of certain types of carcinoma and leukemia, localization of brain tumors, determining the physiology and activity of the thyroid, testing kidney and liver function, and measuring circulation.

Radio-Active Isotopes in Industry. P. W. JACOE, A.B.[57], described some of the industrial uses of radioisotopes. These included the manufacture of energy and isotopes by the reactors, static eliminators for records, and permanent lights, and checking on the quality of many industrial products.

Cortico-Cancellous Block Bone Grafts for Long-Bone Defects. DR. CHARLES F. GREGORY [58] reviewed seven long-bone defects treated by implanting blocks of iliac bone. Gaps in long bones in the upper extremity can be effectively treated by implantation of block grafts of cortical and cancellous bone taken from the patient's iliac crest. Such bone transfers succeed in previously infected areas if the infection has first been eradicated or controlled. The grafts may take a long time to become revascularized and reconstituted to the necessary degree of strength for normal function in their new position. In two of the patients reported the grafts fractured. Continuation of internal fixation for a considerable period of time is recommended. The fractured grafts heal if they are treated as a fracture and are adequately protected.

Stepcutting the graft ends and the recipient host bone produces a stable fit and reduces the danger of rotary motion at the bone junctures when an intramedullary rod is used for fixation.

One case report demonstrated a muscle-pedicle iliac graft to the forearm.

In discussion, DR. JOE B. DAVIS [59] and the author examined the theoretical advantages of muscle-pedicle bone grafts. Dr. Davis, who had reported a similar case at the 1957 meeting, reviewed the ideal characteristics for bone-replacement tissue.

Post-Anesthesia Suggestion in Orthopedic Surgery. DR. SEYMOUR L. ALBAN [60], DR. HARRY ALBAN [61], and DR. BERNARD COOPERMAN [62] reported a series of patients in whom they took advantage of the suggestible state engendered by anesthesia to make them more comfortable after operation and more amenable to performing the usual postsurgical exercises. This procedure is based on the premise previously reported by Dr. David Cheek—that a patient in a surgical plane of anesthesia is able to hear meaningful sounds made in the operating room. This awareness is usually on a subconscious level and memory of these experiences can be evoked through hypnosis.

Hypnosis was not utilized either before or after anesthesia but only during the awakening phase. After the pharyngeal reflexes had returned, the authors made suggestions to the patient consisting of positive assurance that he would be comfortable, would feel hungry, would have a general feeling of well-being and contentment, and would perform the specific activities that might be applicable to the particular operative procedure performed.

The authors utilized this method in approximately 150 patients. Although evaluation of the results, of course, is difficult because the factors involved are in the subjective realm, the authors were able to compare the results from this method in seven other patients who had had previous orthopaedic procedures without postanesthesia suggestion.

In discussion, DR. R. ROBERT COHEN [63] emphasized the fact that the phenomenon described by the authors is not due to the specific anesthetic agent used, but may be induced by any narcotizing drug. This tended to confirm the conclusions of Dr. J. Stephen Horsley, a British psychiatrist, who produces the same effects with intravenous pentothal in amounts of from two to four cubic centimeters.

The Management of Fractures of the Hip Associated with Senile Osteoporosis. DR. MARSHALL R. URIST [64], DR. PAUL VINCENT [65], DR. ROBERT MAZET, JR.[1], and DR. CHARLES O. BECHTOL [66] reported on the incidence of severe postmenopausal or senile osteoporosis of the spine in patients with fractures of the hip, and gave a preliminary report on the use of collapatite as a

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61. 1957 Pacific Avenue, Long Beach 6, California.
62. 1957 Pacific Avenue, Long Beach 6, California.
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substitute for metal for internal fixation of fractures of the neck of the femur in patients with severe osteoporosis.

They emphasized that the large number of unsatisfactory results in fractures of the hip have been attributed to many factors, which include: (1) failure to reduce and impact the fracture; (2) faulty or repeated insertions of a nail; (3) injury to the blood supply to the femoral head; and (4) inadequate internal fixation and detrimental motion at the fracture site. The last is often due to insufficient bone substance to hold the metal inside an osteoporotic femoral neck.

Special roentgenographic examination of 100 consecutive women with hip fracture revealed previously unrecognized osteoporosis in seventy-six. Twenty-four patients who were admitted to four hospitals for fractures of the hip from 1948 to 1953 were found to have had previous roentgenographic examinations of the spine and treatment for severe osteoporosis. The end results of forty-nine intracapsular fractures in patients with osteoporosis were of particular interest because the incidence of failure in this group was higher than that in the unselected cases generally reported in the literature. In a group of thirty patients with osteoporosis who survived for two years, fourteen had non-union and two were treated with prostheses primarily. It would appear from these studies that the chances of restoration of function of the hip joint is only 50 per cent in patients with severe osteoporosis as compared with the approximately 70 per cent chance in unselected or non-osteoporotic patients, as reported in the literature.

The second portion of the presentation was a preliminary report on the use of collapatite pegs instead of metallic nails for intramedullary fixation of the neck. Collapatite is a derivative of human or beef cortical bone that has been excised under sterile technique at autopsy or slaughter and cut in strips to include the full thickness of the cortex (usually seven to eight millimeters). They are ten to twelve centimeters in length, and from two to two and one-half centimeters in width. These pegs are thus at least nine millimeters wider than the standard trifin nail and are wide enough to fill the hollow necks of osteoporotic femora. The collapatite was prepared from these strips of cortical bone by the extraction of all the intracellular and extracellular protein except for the collagen and bone mineral, in so far as this is possible. Collapatite is very slowly absorbed and well tolerated by the tissues. Experiments with collapatite show that it is not incorporated in the same fashion as autogenous bone but is invaded by new bone from the host bed at from four to six weeks. The importance of impacting the neck of the femur into itself or into the head over the collapatite peg was emphasized, and the necessity for open reduction of the fractures to be sure that impaction is accomplished in a satisfactory position was likewise stressed.

Fractures of ten osteoporotic hips were treated with collapatite pegs. The immediate results were excellent in six patients and poor in one. Three patients died of unrelated disease before the end of the first year. Ten additional hips were treated too recently to evaluate, except that good internal fixation was obtained in nine. Reports of these patients will be submitted in later communications.

In discussion, Dr. Donald E. King [67] encouraged further trial in the use of the collapatite pegs and stressed the importance of open reduction of these intracapsular fractures to get satisfactory reduction and impaction of the neck and head.

Silent Ulnar Nerve Adhesions: A Cause of Limited Elbow Function. Dr. John E. Stewart [38] presented a case history of a minor olecranon fracture in which unsuspected adhesions around the ulnar nerve ultimately proved to be the cause of persistent limitation of elbow motion.

Eleven months after the original operation on the patient discussed severe arm pain and very limited motion of the elbow still persisted despite wedging casts, manipulation under anesthesia, and extensive supportive therapy. The ulnar nerve was then explored and found to be subluxated behind the medial epicondyle and adherent for one inch proximal and one inch distal to the level of the epicondyle. On neurolysis and anterior transplant of the nerve, symptoms rapidly subsided and motion returned. Six months after the nerve transplant, the patient was asymptomatic.

The Tight Heel Cord. Dr. Stanley S. Tanz [68] analyzed 200 normal subjects in an attempt to determine the incidence of tight heel cords. The test for judging the presence of a tight heel cord, according to the standard recommended method, consists in dorsiflexion of the inverted foot with the knee extended. This locks the subtalar joint and tightens the gastrocnemius.

Although it is generally felt that normal dorsiflexion should be to a right angle or to 10 degrees beyond a right angle, the author's studies indicated that there is marked individual variation in the tightness of the heel cord and that tight heel cords are not infrequently present in feet that are neither pronated, flat, nor disabled.

Testing for a tight heel cord with the foot in maximum inversion does not measure true heel-cord tightness. In the author's opinion heel-cord tightness, when present, is best demonstrated by dorsiflexing the foot in the neutral position with the knee extended.

Anterior Transposition of Posterior Tibial Muscle in Equinovarus. Dr. J. Irving Tuell [69] reported the results of transfer of the posterior tibial tendon through the interosseous

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membrane, by a technique similar to that described by Watkins in 1954, in eleven feet with either acquired or congenital equinovarus deformity. The results were excellent in ten of the eleven feet. In all of the feet with excellent results the transplanted posterior tibial muscles stood out strongly when the patients walked on their heels, and excellent strength of the transplanted muscle was found when the patients were requested to perform active dorsiflexion of the foot. However, in none of the feet could the tendon be seen to contract during the swing phase, emphasizing the fact demonstrated with electromyography by Close—that the posterior tibial muscle transplanted through the interosseous membrane does not convert to swing-phase activity but continues to contract during the stance phase as it did before the transplant.

It was suggested by Dr. Tuell that the excellent results are due to the removal of the continual pernicious pull of the posterior tibial tendon in its original deforming location; and then to the intermittent, although possibly inefficient, activity of the muscle in its new location as a dorsiflexor.

The results of transfer are far better than the results obtained by simple lengthening of the tendon or lengthening combined with a posterior medial release in cases of recurrent equinovarus deformity.

FORUM ON FUNDAMENTAL PROBLEMS IN ORTHOPAEDIC SURGERY

MEETING OF THE AMERICAN COLLEGE OF SURGEONS

September 28, 1959

AS PREPARED BY CRAWFORD J. CAMPBELL, M.D., ALBANY, NEW YORK

Following are summaries of the papers presented at the Orthopaedic Section of the Forum on Fundamental Problems presented at the 45th Annual Clinical Congress of the American College of Surgeons on Monday, September 28, 1959, held in Atlantic City, New Jersey:

Fat Embolism: Correlation of Serum Lipase Level with the Incidence of Lipuria. DR. FEDERICO ADLER, DR. SING-PING LAI, and DR. LEONARD F. PELTIER [1] have continued with their basic work on fat embolism. This was essentially a correlation of the incidence and time of occurrence of lipuria with the serum lipase level. Forty patients were carefully studied after intertrochanteric fracture or crushing injuries to the soft tissue or skeleton. Although only a few patients had clinical manifestations of fat embolism, 57.5 per cent had lipuria and 52.5 per cent had an elevated serum lipase, 25 per cent had an elevated lipase with lipuria, 32.5 per cent had a normal lipase with lipuria, 27.5 per cent had an elevated lipase without lipuria, and 15 per cent had a normal lipase without lipuria. The patients were studied during the first week after trauma. The lipuria occurred usually during the first three or four days after injury, whereas the elevation of the serum lipase usually occurred from five to eight days after injury. These findings fitted into the basic concepts of fat embolism as postulated by the authors: that there is an initial stage of mechanical obstruction by fat emboli which is not recognized clinically and this coincides with the time that fat is found in the urine. There is then a latent period during which the hydrolysis of neutral fat occurs in the lungs with the freeing of the toxic fatty acids, which, if they are present in sufficient quantity, eventually give rise to the clinical manifestations of this disorder. The elevation of the serum lipase, which was noted from five to eight days after injury, results from the enzymatic activity associated with this latter process.

Prophylactic Antibiotics in Elective Operations on Bones, Joints, and Tendons. DR. MELVIN OLIX, DR. THOMAS KLUG, and DR. WILLIAM S. SMITH [2], in a study of 500 consecutive patients, gave every other patient 400,000 units of penicillin G and 0.5 gram of dihydrostreptomycin every twelve hours for an average of from three to seven days after operation. The group receiving the prophylactic antibiotic therapy had a 5.9 per cent increased incidence of wound infections as compared with the control group. There was also a slightly higher incidence of pulmonary, urinary, and vascular complications in the group receiving prophylactic antibiotics.

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2. University Hospital, Columbus 10, Ohio.

The Treatment of Chronic Osteomyelitis with High Dosages of Antibiotics Using the Isolation-Perfusion Technique. Dr. Robert F. Ryan [3], Dr. George W. Beddingfield, Dr. George C. Hottinger, Dr. Keith Reemtsma, and Dr. Jack Wickstrom have extended their work on isolation and perfusion techniques to chronic osteomyelitis. On the basis of their experimental work on antibiotic toxicity on the isolated and perfused extremities of sixty-eight dogs, appropriate dosages of bacitracin, chloramphenicol, and madribon were established. Neomycin and spontin were discarded because they accelerated clotting. Six patients with severe chronic osteomyelitis, which had for years been resistant to all forms of medical and surgical treatment and in which the predominating organism was either proteus, pseudomonas, or staphylococcus, were considered suitable for the isolation and perfusion treatment of the affected limb with bacitracin, chloramphenicol, and penicillin. An example of the dosage shows that for the lower extremity 150,000 units of bacitracin, four grams of chloramphenicol, and 5,000,000 units of pencillin were used. All six patients showed an initial improvement, although six have shown some recurrence of drainage and will require surgical management. Dr. Ryan and his associates warn, however, that this was essentially a short-term follow-up, being less than a year, and that the extreme chronicity of this disease makes interpretation of any short-term results of such a new treatment particularly hazardous.

The Electrical Response of Human Skeletal Muscle to Passive Stretch. Dr. Robert A. Becker [4] postulated on the basis of electromyograms a dual neuromuscular system in man: one voluntary, following the all-or-none law; and the other tonic and found in only the postural muscles. In his records he noted trains of high-frequency positive wave forms which were initially low in amplitude and which were related to the phase of the stretch cycle. These wave forms were potentiated in amplitude, frequency per unit time, and absolute amount by passive stretching. This wave pattern appeared in his recordings in both normal and diseased conditions. Dr. Becker stated that the evidence for a tonic muscle fiber system in man was in the distinctive electrical responses to passive stretch which have been found in the postural muscles of patients with clinical syndromes that are characterized by an increased irritability of the skeletal musculature. Electronic analysis indicates a basic difference in the mode of production of the wave forms. Since the tonic muscle fiber system does not follow the all-or-none law, its activity can be potentiated by pathological conditions in the tonic fibers themselves or anywhere in the spindle control circuit. This potentiation of activity was also demonstrated clinically by hyperirritability of the involved musculature and electronically by measurable responses to passive stretch. If further experimental work substantiates the finding of a tonic muscle fiber system, some of the basic concepts in neuromuscular physiology will be altered.

Immunologic and Histologic Investigation of Heterogenous Bone Transplants. Dr. W. H. Siegrist [5] and Dr. W. F. Enneking attempted to determine the presence or absence of circulating antibodies against transplants of fresh heterogenous bone and to determine if the rejection mechanism can be suppressed by immunization techniques. Hamsters were used as the recipients for femoral transplants from rats. Some autogenous transplants in hamsters were done as histological controls. On the third day after transplantation, each hamster was given an intraperitoneal injection of one cubic centimeter of the filtrate obtained from the bone of a specific donor rat. The injections were continued daily through the fourteenth day after the transplantation. Fifty of these immunized animals were sacrificed on the thirtieth day after transplantation. Fifty non-immunized animals received rat femoral transplants as controls. With the methods of immunization used in this study, Dr. Siegrist and Dr. Enneking were unable to produce any detectable antibodies in the sera of animals which had received transplants of fresh heterogenous bone. The absence of circulating antibodies was believed to be probably due to an error in the method of preparation of the bone extract. The histological evidence that the inflammatory process around the transplant was consistently more intense in the animals that had received the extract suggested, however, that the extract did contain antigenic substances.

Free Autogenous Whole Joint Grafts. Dr. John R. Alger and Dr. Martin A. Entin [6] gave a preliminary report on autogenous grafting of whole small joints in dogs. Eighty-nine metatarsal phalangeal joints were transplanted (1) to replace other joints of similar size, (2) into soft tissues, and (3) into the medullary cavity of bones. Dr. Alger and Dr. Entin said that their short-term follow-up indicated that autogenous grafting of small joints may give good function. A histological section showed some preservation of the joint space. Temporary storage of the joint within either the soft tissues or bone resulted in fibrosis with a poor functional capacity when transplanted later.

An Experimental Study of the Effects of Subtrochanteric Osteotomy and Partial

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6. 1538 Sherbrooke Street, W., Montreal, Quebec, Canada.

Synovectomy at the Hip. Dr. S. S. Shulman [7] subjected sixty albino rats to subtrochanteric osteotomy and thirty-four albino rats to partial synovectomy. After the osteotomy a decrease was noted in the width or thickness of the capital epiphysis, with premature ossification of the head, when compared with the other side. There was also destruction of the mid-portion of the epiphyseal plate. After synovectomy the head did not show premature ossification, but there were invasion and destruction of the capital epiphyseal plate. Deformities of the greater trochanter were also found after partial synovectomy. Dr. Shulman believed that the results indicated that there were induced vascular changes, which he described as an increase in the vascularity of the head after these procedures.

The Use of Freeze Dried Full Thickness Skin Homografts to Replace the Achilles Tendon in Dogs. Dr. J. Otto Lottes [8], Dr. W. Edward Lansche, Dr. Warren G. Stamp, and A. E. McGinnis replaced measured lengths of Achilles tendon in mongrel dogs with freeze-dried, full-thickness skin homografts. The authors stated that the cutis portion of the graft was gradually transformed into tissue which resembled tendon microscopically, whereas the epidermis persisted and was walled off by a chronic inflammatory response. The functional result in the dogs was good.

A Study of the Growth of Human Epiphyses of the Tibia and Femur. Dr. Alfred E. Kritter and Dr. Walter P. Blount [9] studied the growth of the long bones in children, using stainless-steel markers and standard teleoroentgenograms and orthoroentgenograms. The authors noted that a stapled epiphysis continued to grow at a rate of about 20 per cent of normal. After an operative procedure in the area of the epiphyseal plate, they noted a temporary acceleration of growth in the other epiphyseal plates of that extremity. After the removal of the staples, a temporary acceleration of growth was also noted. On the basis of these studies the authors believe that growth after epiphysiodesis, as indicated by change in the total bone length is actually due to stimulation of the other epiphyses of the bone involved. This conclusion could be reached only by observation of the relationship of the ends of the long bones to the inserted markers.

Extraosseous and Intraosseous Blood Supply of the Tibia. Dr. George E. Nelson [10], Dr. Patrick J. Kelly, Dr. Joseph M. Janes, and Dr. Lowell F. A. Peterson studied a series of normal human tibiae with several injection techniques previously employed on other bones. They found that there was little evidence that periosteal vessels play a significant role in the blood supply of normal human tibiae. The major vessels to the diaphyses are from the nutrient artery and its branches which enter the cortex from the endosteal surface. The ends of the bone are richly supplied by metaphyseal vessels entering from around the periphery of the bone. Frequent anastomoses were noted between the metaphyseal and nutrient-artery vessels.

The Second Injury Phenomenon as It Relates to Callus Formation. Dr. Richard F. Slager and Dr. William S. Smith [11], using roentgenograms as the only criteria for evaluation of the reparative process, could find no improvement in the healing rate after fractures of the femur produced in thirty rats five weeks after an initial fracture of the opposite femur when the healing rate in these second fractures was compared with that of single fractures produced in the same number of control rats.

Effect of Immobilization on Ca^{45} and Sr^{85} Metabolism with Special Reference to Scoliosis. Dr. F. Bronner, Dr. J. R. Cobb, Dr. P. D. Wilson, Jr. [12], Dr. J. A. Nicholas, and Dr. Paul Saville studied a seventeen-year-old boy who underwent surgical correction for congenital scoliosis by means of conventional balance and isotope techniques. The authors noted that immobilization of this patient with scoliosis in a plaster cast resulted in a moderate increase in the urinary calcium output, with no concomitant changes in the excretion of phosphorus or nitrogen. A marked rise in the urinary calcium ^{45} output was seen after immobilization; this was interpreted as reflecting a diminution of the normal rate of excretion of strontium ^{85}. It was concluded that strontium enters the skeleton by processes that are relatively independent of bone-tissue metabolism.

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8. St. Louis Hills Medical Center, 6500 Chippewa, St. Louis, Missouri.
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12. 535 East 70th Street, New York 21, N. Y.

JAPANESE ORTHOPAEDIC ASSOCIATION

The papers reviewed from the meeting in April 1959 of the Japanese Orthopaedic Association were from the orthopaedic departments of the universities, medical schools, or hospitals noted. In Japan, all such reports are instigated by, or under the close direction of, the professor or director of such services. Where the professor or director's name has not been noted among the list of authors, it is an error that the editors have been unable to correct, and they herewith apologize to those who are not listed.

A résumé of each paper follows:

Study of the Bone Matrix and Metabolism during the Healing of Fracture by Means of S^{35} Macro-Autoradiography. Dr. Ishigami [1] and Dr. Yoneda investigated by macro-autoradiography the localization of deposit of S^{35} during the healing process of fractures in mice. Exposures were continued up to 317 days after injection. Seen within four days after fracture was lineal S^{35} deposition corresponding with marked new growth of periosteal mesenchymal tissue. The periosteal mesenchymal tissue became differentiated into cartilaginous structure at the eighth day after fracture, and deposition was distributed widely in the cartilaginous cells. S^{35} was also markedly concentrated in the border layer between the cartilaginous tissue and the connective tissue. At the second week the autoradiograph showed the outline of whole bone produced by the deposition. The third week after fracture the S^{35} deposition became even throughout, the mature cartilaginous tissue being replaced by new-bone trabeculae.

The Amino-Acid Contents in Normal Bone and Callus by Ion Exchange Chromatographic Method. Dr. Morotomi [2], Dr. Fujita, and Dr. Sakane, in experiments on the adult rabbit, separated the amino acid present in the hydrochloric acid-hydrolysate of whole bone and callus during fracture repair.

Amino acids of relatively large amount contained within normal bone are alanine, glycine, glutamine, lysine, arginine, and aspartic acid. Small amounts of methionine and cystine are also present.

Values for all amino acids in callus, with the exception of cystine, are increased. There is a remarkable increase of lysine and of aspartic acid in the course of fracture healing.

Electromicroscopic Studies in the Field of Orthopaedics. The Healing of Fractures. Dr. Kashiwagi [3], Dr. Tomatsuri, Dr. Hirohata, Dr. Toda, Dr. Kinbara, and Dr. Okada fractured the diaphyseal areas of the tibiae of rats and studied the process of union by electron microscopy.

The results of the experiment showed that: (1) undifferentiated mesenchymal cells, as well as periosteal cells, play a role in the development of callus; (2) the process of collagen formation originated from the surface of the cell membrane and its processes, and no fibrils were observed in the cytoplasm of the cells; (3) when the fibrils of the intercellular substance increased in number and thickness and were lined parallel, intramembranous ossification resulted. When the fibrils of the intercellular substance were connected loosely, cartilaginous ossification appeared; (4) in the process of intramembranous ossification, osteoblasts and osteocytes appeared to be directly transformed from the mesenchymal cells; and (5) in the process of cartilaginous-bone formation, the cartilage undergoes degenerative changes and is gradually replaced by new bone by osteoblastic activity.

The Effect of Adrenocortical Hormone on Healing of Experimental Fractures. Dr. Otani [4] fractured the lower limbs of albino rats, and investigated the effect of the injection of cortisone (ten milligrams per kilogram of body weight, twenty-five milligrams per kilogram of body weight, fifty milligrams per kilogram of body weight, and seventy-five milligrams per kilogram of body weight) and the effect of adrenalectomy.

The results of experiments showed that: (1) cortisone inhibited increase of bone weight; (2) roentgenographically, cortisone and adrenalectomy do not change the fracture-healing process; (3) histologically, cortisone inhibits fracture healing in the early stage and may delay fibroblast formation and osteoid. Small doses of cortisone caused no change in the mid-stage and end stage. Larger doses disturbed enchondral ossification, even as late as the sixth week after fracture. Adrenalectomy inhibits cartilage formation in the early and mid-stages of fracture healing, but in the end stage no difference was seen.

1. The First National Hospital of Tokyo.
2. Kyoto Prefectural Medical College.
3. Kobe Medical College.
4. Nagoya National Hospital.

Experimental and Clinical Studies of the Influence of Ossopan upon the Fracture Healing. Dr. Fujimoto [5], Dr. Takeuchi, Dr. Hokari, and Dr. Makino investigated, both clinically and experimentally, the effect of ossopan on the healing of fractures and considered it suitable for use in delayed healing.

Experimental Studies on Compound Fractures in Rabbits. The Fate of Denuded Bone. Dr. Kashiwagi [3], Dr. Ito, and Dr. Inada said that many open fractures with large skin defects are encountered. To clarify treatment of patients with such conditions, they performed experiments on rabbits to observe the changes in denuded bone.

Denuded bone appeared necrotic after the second week on roentgenographic examination and after one week, on histological section. Complete demarcation was manifested three weeks after the operation, by both histological and roentgenographic findings. No callus formation was seen, even after six weeks of observation. Similar changes were demonstrated when using radioactive phosphorus.

If denuded bone was covered early with healthy skin by relaxing incisions, or skin grafts, the fractured ends healed with proper callus formation.

Experimental Study on the Repair of Injury to the Epiphyseal Cartilaginous Plate. Dr. Iwahara [6] and Dr. Yoshida performed a series of experiments on the distal ulnar epiphyseal cartilaginous plate of the young rabbit.

The influence on longitudinal growth was observed by macroscopic, roentgenographic, and microscopic examinations.

The authors found that: (1) the disturbance of bone growth by vertical incision across the plate is slight; (2) marked disturbance follows even partial metaphyseal resection, and premature closure of the plate occurs eight weeks after injury; and (3) in epiphyseal separation, non-displacement or displacement less than one-fourth of the diameter of the epiphysis disturbed growth but little. Displacement of more than one-fourth of the diameter was usually followed by premature closure ten weeks after injury.

Experimental Study of the Use of Coelinvar for Orthopaedic Purposes. Dr. Iino [7] and Dr. Sohma said that coelinvar is a malleable stainless steel made by Dr. Masumoto and Dr. Saito in the Metallic Materials Laboratory of Tohoku University. The constituents are cobalt, nickel, chrome, and iron.

The methods used in the experiment were: (1) a one-millimeter-thick wire of coelinvar was placed in the proximal metaphyses of rabbits' tibiae. Histological study was made at two-week intervals for twelve weeks, comparing the effects of coelinvar and of two commonly used types of steel; and (2) intramedullary nails of coelinvar were inserted in young rabbits' tibiae. Changes in the form and structure of the long bone were observed by roentgenogram, by measurement, and by microscope.

The authors found that coelinvar is less irritating to bone than 22A or 18-8 steel. Bending of a fractured tibia may take place after inserting a medullary nail of coelinvar, without demonstrable fracture, although external callus does form.

Complications in Intramedullary Nailing. Dr. Takase [8], Dr. Nomura, Dr. Kataoka, Dr. Harada, and Dr. Nakamura said that thirty-eight fractures of the femur were treated by intramedullary nailing in their clinic during the period from 1954 to 1958. There were five instances of non-union and three of delayed union. There were also bent or broken nails.

Histological examination showed that the intramedullary nail delays callus formation and regeneration of the bone marrow.

A New Type of Internal Splinting for the Fracture of Long Bones. Dr. Mizuno [9], Dr. Yamasaki, Dr. Huzisita, Dr. Arima, Dr. Isida, and Dr. Nanbu evaluated the methods of internal splints for fractures of long bones. Bending experiments were attempted on transverse fractures. The mechanical weaknesses of various plates were revealed. The authors suggest use of an arch type of plate with sharp teeth on both edges.

Follow-up Studies of Bone and Joint Tuberculosis (Third Report). Dr. Katayama [10], Dr. Marumo, Dr. Sawada, and Dr. Yoshinaga followed 517 cases of bone and joint tuberculosis for from two to eleven and a half years. Reactivation of the disease occurred in nineteen (10.6 per cent) of 117 conservatively treated patients and in ten (2.9 per cent) of the 339 patients operated on. Reactivation in the conservatively treated group was believed dependent on poor selection of cases. Reactivation in the group operated on was caused by incomplete removal of

5. Shinshu University Medical College.
6. Keio University School of Medicine.
7. Tohoku University, Sendai.
8. Kanazawa University.
9. Osaka City University Medical School.
10. Tokyo Jikei-Kai Medical College.

foci, insufficient antibiotic therapy, or too rapid return to activity. Remaining joint function varied, depending on the joint involved and the operative method. Early diagnosis and early treatment promoted the best results.

Study of the Sequela of Injury to the Ankle Joint. Dr. Morimoto [11] observed by roentgenogram the injured ankle joints of 496 patients and investigated the correlation between the shape of the space and the abnormal mobility after injury. The ratio of the width of the space between the tibia and talus on the lateral side to that on the medial side (as seen in anteroposterior stress roentgenograms) was used as a measure of abnormal mobility. The shape of the space was most apt to vary in ankles in which abnormal mobility was present. Changes in both shape and hypermobility were commonly present in patients whose symptoms persisted.

Fracture of the Calcaneus. Dr. Murakawa [12], Dr. Suda, Dr. Watanabe, Dr. Tsuda, and Dr. Monden, since February 1955, treated twenty-six patients with thirty-two fractures of the calcaneus. Involvement of the subtalar joint was found in 78 per cent of the patients.

Open reduction is considered to be the best method and is recommended in this type of fracture.

Open Reduction of Fracture of the Neck of the Femur. Dr. Morita [13] and Dr. Tutumi treated sixteen cases of fracture of the neck of the femur during the past two years. The procedure of closed reduction and internal fixation was carried out in eight hips; satisfactory results were obtained. Aseptic necrosis occurred in three of the eight hips treated by open reduction and internal fixation.

The Development of Immune Products in the Rabbit after Ox-Bone Grafting. Dr. Aoike [14] and Dr. Iiji, by serological methods, studied the immunological reaction preventing successful bone transplantation.

Rabbits were immunized by the administration of ox bone or bone fractions in the following forms: fresh bone, pulverized bone, saline extract, bone collagen, and osseomucoid. Immunological studies of these animals were carried out using the precipitin test, complement-fixation test, sensitized red-cell agglutination test, and Coombs' test. None of these tests proved the definite development of immune products.

Serological investigations were pursued in five patients for whom ox bone was used as a graft. One showed an allergic response by intracutaneous reaction to ox osseomucoid. The immune products in this patient were also detected by the complement-fixation test.

Experimental Studies of Heterogenous-Bone Transplantation. Dr. Kawamura [15], Dr. Hosono, Dr. Takahashi, Dr. Tomita, Dr. Nakazoe, Dr. Hirayama, and Dr. Kido transplanted ethylene-glycol-extracted dog bone into the iliac crest of rabbits. The results showed that: (1) the line between transplant and host remained clear for three weeks. Rarefaction of the transplant began at three to four weeks. At five to six weeks this became more pronounced. At ten to twelve weeks the transplant, as a whole, gradually changed its form through calcium resorption and deposition from the host; (2) histologically, the granulation-tissue formation and allergic reaction were manifested early. At three weeks there was indication of osseous connection between transplant and host. At four to six weeks allergic reaction was decreased, and invasion of blood vessels into the transplant, with lacunar resorption and primitive bone-marrow formation, were noted. At nine to ten weeks considerably advanced osseous connection between transplant and host was seen; and (3) immunologically, the precipitation test was negative in all cases investigated.

Transplantation of Heterogenous Bone. Dr. Nishi [16], Dr. Nikuno, and Dr. Shoji recommended the application of heterogenous bone when transplantation is carried out after decalcification of the grafts. Organic substances acting as antigens disappeared with calcium components.

Such transplanted grafts are surrounded by abundant callus within two to four weeks. Ossification occurs soon after, completely replacing the transplanted bone tissue. Although the process requires more time than transplantation of autogenous bone, the authors have been successful in several instances in human subjects.

Experimental Studies of Cadavera Bone as Homogenous-Graft Material. Dr. Kodama [17] and Dr. Nasu said that in Japan most bank bone is obtained from ribs excised during thoracic surgery. This source of bone is becoming reduced. The use of cadaver bone is limited by legal and familial restrictions. It is imperative to remove these difficulties.

11. Chubu-Rosai Hospital.
12. Okayama Labour Accident Hospital.
13. Wakayama Red Cross Hospital.
14. Tokyo Medical and Dental University.
15. Sapporo Medical College.
16. Toho University School of Medicine.
17. Okayama University Medical School.

Experiments were performed on rabbits in an attempt to determine how long after death bone obtained would be aseptic and useful for grafting. The rabbits were killed, and specimens taken from the bone marrow of the tibia, calcaneus, and iliac crest were cultured three, six, nine, twelve, twenty-four, thirty-six, and forty-eight hours after death. At the same time, post-mortem homografts taken from the iliac crest of the rabbit, immediately, twenty-four, and forty-eight hours after death, were implanted in a defect of parietal bones. Comparison was then made of the grafts just described and of autogenous grafts. (This experiment is reported in full in the *Journal of the Japanese Orthopaedic Association.*)

Clinical Experiences with Frozen Homogenous-Bank-Bone Grafting in 104 Cases. Dr. Amako [18] and Dr. Kaneko reported the results of 104 frozen homogenous-bank-bone grafts on ninety-eight patients during the last five years.

The procedure was as follows: (1) banked bone was preserved at −18 degrees centigrade for from two to 485 days. The length of storage time apparently had no effect on the result; (2) twenty-three (22 per cent) of the 104 grafts failed to heal by first intention. The grafting was followed, most often in two weeks or so, by the onset of fever of unknown origin (antigen-antibody reaction) in the patients in thirty (28.8 per cent) of 104 procedures; and (3) the grafted bone united with the host bone in sixty-nine (84 per cent) of eighty-one non-infected grafts. Roentgenographic examination made after operation showed that the transplanted graft was resorbed to some extent in approximately 40 per cent of the grafts.

The final result was excellent in 48.2 per cent of the grafts.

An Experimental Study on Intra-Articular Bone Transplantation. Dr. Iwahara [6] and Dr. Nakamura transplanted autogenous iliac bone into defects of the joint surface of the knee of rabbits.

The results suggested that defects of the weight-bearing joints could not be satisfactorily repaired.

Influence on Osteosynthesis Caused by Burning of Bone. Dr. Kinoshita [19], Dr. Hirakawa, Dr. Boda, Dr. Kusunoki, Dr. Oguma, Dr. Matsuba, and Dr. Imada conducted animal experiments with mature dogs to clarify the influence of the burning of bone on osteosynthesis. The burning was caused by friction developed by power instruments.

Cuts were made with a power bone saw, the bone saw being cooled in controlled cases by saline solution and not cooled in other instances. Roentgenographic and microscopic examinations were made up to nine weeks after operation. Union was present in the controls at six weeks, but absent in the burned areas at nine weeks.

Experimental and Clinical Studies on the Use of Bone Chips in Prepared Coagulated Blood for the Filling of Osseous Defects. Dr. Kawamura [20] gave details of the preparation of bone chips and the implantation in coagulated blood to form a semisolid mass. This mass was used to fill defects in animals and, later, in human beings. The results were regarded as satisfactory.

The Relation between the Temperature of the Surface of Granulation Tissue of Skin Defects and That at the Base of Pedicle Skin Grafts, Compared with the Distribution of NA [24] at the Same Locations. Dr. Hiroshi Ogata [21] said that the temperature readings he made indicated that the greatest increase was over granulation tissue, much less at the base of the pedicle skin graft, and even less over normal skin. The Na [24] distribution, however, showed the greatest amount in the healthy skin around the wound, the least amount in the granulation tissue, and a moderate amount at the base of the pedicle skin graft.

Wound Healing Impaired by Cortisone Therapy: Prevention of Cortisone Effect by Leucine. Dr. Taro Hoshino [22] said that his experiments included a control group of animals treated with repeated cortisone injection and an experimental group treated by cortisone injection in addition to leucine in the diet.

The depression of wound healing caused by cortisone injection seemed to be overcome by the addition of leucine to the diet.

Clinical application of the experiment was not attempted.

Survey of the Course and Treatment of Burn Scars Produced by the A-Bomb Explosion at Hiroshima. Dr. Ishida [23] and Dr. Morinaga reported on 108 patients with such burns examined during the past ten months, and on eighty-five additional patients whose scars were operated on within the past two years.

18. Kyushu University, Faculty of Medicine.
19. The Chugoku Labours Casualty Hospital.
20. Kyoto Furitsu University.
21. Central Railway Hospital, Tokyo.
22. Wakayama Medical College.
23. Hiroshima A-Bomb Hospital.

Although in 30 per cent of the patients reactivation of the scars was seen to occur even late after exposure, in all others the keloids in the scars were decreasing and the scars were returning to the appearance, texture, and histological findings usually noted in simple burn scars. Histological findings in the excised scars of the surgical patients indicated a decrease in reaction and a return to normal scarring in the patients operated on within the last two years, compared with sections taken from similar patients who were operated on five years ago. In 65.7 per cent of the patients postoperative healing was satisfactory, but in 34.3 per cent healing was markedly deferred or did not occur when incisions were made through such scars.

Experience of Fusion Operation of the Ankle Joint in Children. Dr. Yano [24], Dr. Shin, and Dr. Shibata followed thirty-four children, on whom ankle fusion had been done, for from six months to eight years. The results were excellent in 47 per cent, good in 44 per cent, and poor in 9 per cent of the patients. The authors believe the results depended on operative technique and indicated that the earliest age for such operation appears to be five years.

Iliofemoral Intramedullary Nailing for Arthrodesis of the Hip. Dr. Onji [25] and Dr. Kurata discussed eight patients with osteo-arthritis, tuberculosis, or pathological dislocation of the hip in whom the head of the femur was removed and the trochanter placed in the socket after first driving an intramedullary nail up through the acetabulum. With the trochanter in the acetabulum the nail was then driven downward into the femoral shaft. No plaster casts were used. All hips became solid, and all patients were fully ambulatory within six months.

An Experimental Study of the Effect of Polyethylene for Preventing Adhesions on Suture of Peripheral Nerves. Dr. Hiroshi Wada [26] said that the placement of polyethylene around nerve sutures was not satisfactory either in preventing adhesion or facilitating repair. Furthermore, the material had to be removed because of its action as a foreign body.

Experimental Studies on Sarcoma Transplants into the Knee Joint by the Use of P^{32}. Dr. Tukio Shimanuki [27] described how Yoshida sarcoma was implanted in the knee joints of albino rats and, ten days later, P^{32} was injected intravenously. Contact roentgenograms and microscopic studies were made, not only of the knee, but also of the thigh, femur, and liver. The density of exposure on the roentgenograms and the histological evidence of cellular activity in the extra-articular metastatic tumors were greater than those in the intra-articular implants.

Statistical Observations of Bone Tumors. Dr. Murachi [28], Dr. Morikawa, Dr. Kato, and Dr. Nagao reported statistical data on 106 bone tumors recorded in the period from 1953 to 1959. The types of tumor and the treatments used were reported; the results, however, were withheld for a further study and a subsequent report.

Clinical Observation and Prognosis in Osteogenic Sarcoma as Related to Histology and Blood Chemistry. Dr. Hanakita [29] and Dr. Makabe reported twelve cases of osteogenic sarcoma in detail, including the microscopic appearance and complete blood chemistry. Prognosis based on such findings was found to be unsatisfactory. The authors felt that early amputation seemed to accelerate development of lung metastases.

Serochemical and Histochemical Studies of Bone Tumors. Dr. Kitagawa [30], Dr. Samejima, Dr. Omiga, Dr. Nakao, and Dr. Nishi studied a series of tumors involving benign lesions, primary malignant lesions, and metastatic neoplasms. Findings indicated that such studies had no diagnostic value in identifying malignant degeneration in benign lesions. Elevation of serum acid phosphatase and increased acid phosphatase content of the tumor seem to be characteristic of extensive giant-cell lesions. No constant findings were present in osteogenic sarcoma. Tissue from osteolytic forms of sarcoma did not contain acid phosphatase, alkaline phosphatase, or phosphorylase, but did contain some glycogen. Prostatic metastatic tumors did not routinely have an increased serum acid phosphatase or an increased content of acid phosphatase.

Electron Microscopy in Six Cases of Human Bone Tumors. Dr. Hirota [31], Dr. Watanabe, and Dr. Maruta reported on electron microscopic findings in bone lesions, which included giant-cell tumor and various forms of sarcoma. In osteosarcoma the pattern seemed to vary considerably with the age of the patient.

Electron Microscopic Observation of Giant-Cell Tumors. Dr. Maeyama [32] and Dr.

24. Kurume University College of Medicine.
25. Nara Medical College and Fuse City Hospital.
26. Nihon University.
27. Fukushima Medical College.
28. Tokyo Kosei Nenkin Hospital.
29. Tottori University.
30. Kumamoto University.
31. Kumamoto University.
32. Kyushu University.

Fujimoto discussed the findings under the electron microscope in fifty-seven giant-cell tumors. The findings seemed to be fairly consistent, except in a malignant condition, where certain typical changes in the cells were observed.

Morphological Study by Electron Microscope in Resorptive Bone Tumor. Dr. C. Y. Want [33] studied tissue from eight giant-cell tumors, three bone cysts, and two cases of fibrous dysplasia. Findings with the electron microscope and with the optical microscope were compared. It was suggested that satisfactory study and classification of similar lesions cannot be made without electron microscopic review.

Studies on Cystic-Appearing Lesions in Bone Tumors. Dr. Shima [34], Dr. Matsuno, Dr. Goto, Dr. Iwata, and Dr. Harada said that they saw, during the past eleven years, 286 bone tumors, 126 of which were extensively studied by histopathological methods. There were sixteen solitary cysts and fifteen giant-cell tumors, most of which showed cystic areas, usually in the eccentric portion of the tumor. In eight patients with fibrous dysplasia, cyst structures could be demonstrated. Fifteen enchondromata had a cystic appearance by roentgenogram, but no cysts were demonstrable histopathologically. In initial stages, myeloma and carcinoma metastases often presented what appeared to be cystlike lesions in the roentgenogram, although none were found on histological examination.

Because of the possibility of a misleading roentgenogram, biopsy and complete histological study seem indicated in all lesions, even when the roentgenographic appearance appears sufficiently characteristic to be diagnostic.

Lung Metastasis and Primary Bone Sarcoma. Dr. Kono [35], Dr. Kozima, Dr. Ishikawa, Dr. Kato, and Dr. Maeda noted that patients with primary bone sarcoma usually succumb from pulmonary metastases. Where such metastases appear and symptomatology therefrom has developed, all patients have died in less than six months.

The authors suggested that patients with osteogenic sarcoma have frequent chest roentgenograms and, if metastasis appears, that excisional surgery be done immediately.

In six patients, metastatic changes in the lung were noted before any subjective symptoms developed. Three were operated on, with resection of the focus in the chest. Two patients were still in excellent condition—asymptomatic and without further metastases seven months after operation. Although these patients are still to be followed further, their results suggest that this procedure may, in the future, salvage some small percentage of similar cases.

Bone Changes Caused by Experimental Feeding with Sweet Pea Seed. Dr. Tsuchiya [36] and Dr. Okuyama compared young white rats fed on a diet of *Lathyrus odoratus* seed with a control group. Studies were done by four special staining methods. An attempt was made to determine the histochemical changes in the matrix of the epiphyseal plate. Difficulties encountered in the procedure and lack of definite results therefrom were recorded for further experimentation.

Prognosis of Perthes' Disease from the Viewpoint of Roentgenographic Findings. Dr. Kono [35] and Dr. Kanazawa surveyed forty-eight hips with Perthes' disease over a period of from four to twenty-seven years. Deformities of the femoral head were classified into three types: spheroid, mushroom, and osteo-arthritic. The osteo-arthritic types were those in which the original radiolucent area, to some extent, remained always present.

Influence of Prolonged Anoxia on the Brain of Fetal, Young, and Adult Rabbits. Dr. Ito [37] and Dr. Ogawa, after experiments on fetal, young, and adult rabbits, described the changes occurring in the brain, incident to anoxia and asphyxia.

A Study on Cerebral Palsy: Etiological Factors Related to Pregnancy and Parturition. Dr. Murisaki [38] and Dr. Okamoto reported on 510 consecutive patients in whom the obstetrical history and charts indicated any deviation from the normal, either in the prenatal, natal, or postnatal period. Thirteen (3.3 per cent) of the children delivered had cerebral palsy. The prenatal factors recorded in these thirteen children were: consanguineous marriage, hemorrhagic diathesis, syphilis, maternal infectious disease, various toxemias, prematurity, and overmaturity. The main precipitating factor involved, however, seemed clearly to be asphyxia neonatorum.

Pattern of Synergies Depending on the Frontal Extrapyramidal Area of the Cerebral Cortex in Monkeys. Dr. Ito [37] and Dr. Takahashi said that they had done specific area abla-

33. Keio University.
34. Hakkaido University.
35. Niigata University School of Medicine.
36. Fukushima Medical College.
37. Hiroshima University.
38. Tokyo Women's Medical College.

tions of the monkey brain, both unilaterally and bilaterally. The experiments were extensive, and detailed results were published in an original paper which can be obtained from the authors.

Training Program for the Upper Extremities in Cerebral Palsy. Dr. Tamura [39], Dr. Kajiwara, Dr. Hanaoka, Dr. Asaka, and Dr. Sakai reported on seventy-three patients treated in a special gymnasium where sixty different types of apparatus have been developed. If improvement is to be obtained specific apparatus must be afforded on an individual basis. With such multiplicity of apparatus, results were improved as to: (1) strengthening muscle transplants, (2) enlarging the range of joint motion, (3) gaining muscular balance, and (4) securing dexterity.

Advantages and Disadvantages of Muscular-Tendinous Transplants in the Lower Extremities of Spastics. Dr. Tamaki [40], Dr. Ishibashi, and Dr. Kanemitsu studied fifty-two cerebral palsied patients by basograms, utilizing stroboscopic photography and the interrupted-light technique. The method was used in evaluating the results secured by conservative training and operative procedures.

Study of Abnormal Gait by Strobophotography. Dr. Kato [41], Dr. Nakajima, and Dr. Morito studied the gaits of postpoliomyelitic patients and of amputees.

Studies on Walking and Limping, by Means of Basograms Dr. Iino [7], Dr. Kurokochi, Dr. Itsuo, Dr. Koiwai, Dr. Ogawa, Dr. Nakamura, Dr. Ono, and Dr. Nakajo studied, by using basograms and strobophotographs, the variation in normal curves in the gaits of adults and children, in addition to various pathological gaits. They were especially interested in specific figures of gait which appeared with congenital dislocation of the hip.

Dynamic Studies of Human Gaits. Dr. Takeshi Gotoh [42] analyzed the forces involved in normal and altered gait. He transmitted electrical impulses into an eight-channel electroencephalographic apparatus and, from the curves, established certain patterns for various gait changes.

The Influence of Ankle Motion on Gait. Dr. Kibi [43], Dr. Kotera, Dr. Ito, Dr. Imamura, Dr. Arima, and Dr. Kinoshita, using basograms and stroboscopy apparatus, studied the involvement of gait owing to ankle disability from various lesions.

Results of Investigation of Patients Crippled by Leprosy. Dr. Tamai [44], Dr. Mizuoka, and Dr. Oyama examined and evaluated 1,209 patients with leprosy. The various types of involvement were described, including the location and degree of involvement and the resultant deformities. The authors also discussed the status of the patients in relation to the Japanese Welfare Law.

Postoperative Personality Change in Children Following Reconstructive Surgery. Dr. Abe [45] and Dr. Shiraishi made a comparison of the results from three standard Japanese psychological tests with those from the Rorschach test, all of which were given to fifty children who had been operated on for orthopaedic problems. In general, all tests gave evidence of the same response. In forty-seven children there was favorable improvement in behavior patterns and personalities; in one, no improvement; and in two there was aggravation of previously existing depressive tendencies.

Histological Study of the Innervation of the Spinous Process and Its Surrounding Tissues. Dr. Aoike [14] and Dr. Ika reported the findings of histological examinations of six freshly excised thoracic spinous processes.

Experimental Studies of the Relationship Between Regeneration of Nerve Endings of Skeletal Muscles and Muscular Function. Dr. Kondo [46], Dr. Kirita, Dr. Sano, Dr. Tokunda, Dr. Nakano, and Dr. Inoue cut and sutured the sciatic trunk in adult rabbits. Degeneration and regeneration of nerve endings were studied at various periods by several staining methods and correlated with the clinical evidences of stimulation threshold, muscle tone, and electromyogram. The protein content of the gastrocnemius muscle and the response obtained by needle electrode (and other tests) were noted. Studies were continued to six months after operation; the progressive changes were recorded and compared by all methods. Morphological regeneration of the nerve endings corresponded with results obtained in the electromyogram. The

39. Osaka Prefecture Rehabilitation Center.
40. Nagasaki Crippled Children's Hospital.
41. Siga Seisien Hospital.
42. Kanto Teishin Hospital, Tokyo.
43. Osaka City University.
44. National Leprosarium Kikuchi-Keifuen, Kumamoto University.
45. Matsubase Crippled Children's Hospital.
46. Kyoto University.

histological findings in the muscles, muscle tone, and content of protein in the muscle did not strictly correspond to one another as recovery took place.

Experimental Study of Peripheral-Nerve Injuries and Pain. Dr. Yamada [47], Dr. Kamihira, Dr. Nodomi, and Dr. Nishio performed various experimental injuries on the sciatic nerves of forty rabbits. The conduction velocity seemed to be an index of the degree of peripheral-nerve injury and of recovery.

Arthroscopic Study of Paralytic Joints Resulting from Peripheral-Nerve Lesion. Dr. Mizumachi [48] and Dr. Hakuno performed arthroscopy on the knees of dogs who had had resection of segments of the femoral and sciatic nerves. Gross examination revealed gradual decrease in the normal synovial villi fat fringes, becoming maximum at nine weeks and gradually recovering in fifteen weeks. Histological examination showed a decrease of fat cells, which gradually recovered. The microscopic findings paralleled the gross arthroscopic findings. The changes were greatest in the lateral half of the joint when the sciatic nerve was sectioned and in the medial side of the joint when the femoral nerve was sectioned.

Arthroscopic Study of Paralytic Joints Due to Central Nerve Lesions. Dr. Mizumachi [48] and Dr. Inoue performed their experiment in two ways. In one the cord was totally severed, and in the other anterior section of the spinal cord was done. Both procedures showed similar results on arthroscopy of the knee and on histological examination. The changes took place somewhat more slowly in the experiment in which only anterior section of the cord was performed.

The findings were those of atrophy due to disappearance of fat cells and replacement with connective tissue, being maximum about the fifth week and continuing thereafter. These experiments were carried on to thirteen weeks after operation and denoted distortion of the synovial lining of the joint incident to the new connective tissue replacing the fat.

Influence of Experimental Injury to the Cervical-Thoracic Cord on Cardiac Function. Dr. Hattori [49] and Dr. Yamasaki, in experiments, produced injuries such as longitudinal incision of the dura, the cutting of posterior and anterior spine roots, and complete transverse section of the cord. Influences on the electrocardiogram were noted, and were most remarkable as to variations of the T wave. In the lower thoracic region little change was noted; otherwise, similar changes appeared throughout the area of the experimentally produced injuries.

Plastic Repair of Skin for Pressure Sores Following Traumatic Paraplegia. Dr. Miyamoto [50], Dr. Hirotani, Dr. Iwatsu, Dr. Kuroda, Dr. Hoshida, Dr. Suguri, and Dr. Mega reported the results of plastic surgery for 161 pressure sores in paralytic patients. Surgery consisted in resection and primary suture in seventy-one patients, free skin-grafting in forty-nine, zigzag plastics with supplementary incisions in ten, and rotation flaps in thirty-one. The rotation-flap method seemed most valuable for extensive lesions. Recurrences after rotation flap were less than for other procedures.

A Study of Joints Fixed in Extension for Various Periods with Special Reference to Vascular Changes. Dr. Mizumachi [48] and Dr. Yamazaki immobilized the knee joints of rabbits for two, four, six, eight, and ten weeks. After injections of India ink into the arterial trees, histological studies were made of the joint structure and of the vascular bed. The changes that occurred after six weeks were so extensive that the authors believed that permanent damage had occurred and complete reversal was impossible.

Experimental Study of Arthroplasty with the Use of Nylon Membrane. Dr. Nagai [51] and Dr. Matsunago placed nylon membrane over the resected femoral and tibial articular surfaces of animals. The inflammatory changes observed receded during the ensuing ten weeks. Late results and the eventual fate of the nylon implants were not recorded.

Experimental Studies of Hip-Joint Damage in Rabbits. Dr. Harada [52], Dr. Yanagidani, Dr. Tanizawa, and Dr. Murota noted gross roentgenographic and histological changes after trauma of the hip joints of eighty-four thirty-day-old rabbits. Seven groups of rabbits were used, each with one of the following trauma: (1) excision of the ligamentum teres; (2) resection of the joint capsule; (3) combined resection of the teres ligament and joint; (4) excision of the acetabular cartilage; (5) excision of the cartilage of the femoral head; (6) combined excision of the acetabular cartilage and the femoral head cartilage; and (7) disruption of epiphyseal cartilage of the capital femoral epiphysis.

47. Tottori University.
48. Yokohama University.
49. Yamaguchi Medical College.
50. Kansai Rosai Hospital.
51. Nagasaki University.
52. Osaka University.

Excision of either the ligamentum teres or the capsule caused slight and temporary changes. Where both were excised, or the cartilage of the acetabulum or femoral head removed, severe changes took place. Disruption of epiphyseal cartilage caused moderately severe changes.

Clinical and Experimental Studies of Fixed Cup Arthroplasty of the Hip. Dr. Iino [7], Dr. Ochiai, and Dr. Nishikawa, in experiments on sixteen dogs, applied cups to the head of the femur and affixed them with screws, extra holes being cut in an attempt to allow synovial fluid to nourish the femoral head.

Nutrition of the head of the femur from synovial fluid, through the holes, failed to take place and irregularity of the cup surface caused destructive changes in the acetabulum. The head and neck of the femur appeared to be well preserved, but this was through the blood supply from the femoral neck.

Functional Significance of the Patella in Movements at the Knee Joint. Dr. Yamada [53], Dr. Kitamuro, and Dr. Shinna studied ten normal male knees and six specimens from cadavera. By photoroentgenography they noted that one of the main functions of the patella was its production of added stability to the knee in the flexed position, the patella being strongly drawn down and centered on the femoral trochlear surface in flexion. The dynamics of transference of force to the tibia through the patella were again demonstrated. The mechanics of the situation produced added momentum on initial extension of the knee joint.

Structure of the Discoid Meniscus as Related to Function and Laceration. Dr. Miyazaki [54], Dr. Araki, Dr. Maeda, and Dr. Maebra said that lateral discoid menisci are extremely common among the Japanese. Laceration of lateral discoid menisci is the most frequently encountered of all lesions of menisci. Horizontal tears through the substance of these discoid menisci occur more frequently than vertical tears.

The authors investigated the fibers in the matrix of intact discoid menisci and related laceration to mechanical pressure of the femoral condyles.

Experimental Observation on the Movement of the Meniscus in the Knee Joint. Dr. Amako [18] and Dr. Kono stripped knees, fresh from amputation, of all soft tissue except ligaments and the popliteus muscle. With the tissues removed, the menisci could be observed by roentgenograms. Translucent models were made of the condyle and inserted in the knees after removal of the femoral components.

The tibial meniscus changed its form most when distorted by motion on the tibia (rotation) and the fibular meniscus most when displaced during motion of the knee (flexion). Average maximum distance of motion was 8.2 millimeters for the tibial meniscus and 11.5 millimeters for the fibular meniscus. Motion is related to the position of the menisci on the tibia, and range of motion in the Japanese is in excess of that in the European or American. The authors believe the tibial meniscus is injured during distortion and the fibular meniscus by impaction.

Report of Arthrodesis of the Shoulder in Poliomyelitic Paralytics. Dr. Wada [26], Dr. Shimokobe, Dr. Minowa, and Dr. Arai performed twenty-four arthrodeses of the shoulder on patients from fifteen to thirty-one years old. In some patients there was extensive paralysis of the whole upper extremity. From their observation the authors believed that the position of mild abduction and 15 degrees of external rotation are the optimum goals.

A New Method for Arthrodesis of Paralyzed Feet in Infants. Dr. Hattori [49] and Dr. Ishikawa reported a series of thirteen operations on the paralytic feet of children four to ten years old. Triple arthrodesis was accomplished by inlaid iliac grafts. The results were compared with those obtained by routine triple arthrodesis. (Many patients, because of age and ossification deficiency, could not have been operated on by routine triple arthrodesis.) When the new technique was used, residual deformity and growth deficiency after operation appeared to be less than after routine triple arthrodesis.

A Study of Calcium Metabolism by the Ca ^{45} Autoradiogram. Dr. Miki [55], Dr. Yokozeki, and Dr. Watanabe injected animals with calcium ^{45} and sacrificed them at periods thereafter. Femora, humeri, and mandibles were sectioned and ground to standard thickness, after which autoradiograms were made. In the animals sacrificed early the heaviest deposit was generalized in the osseous structure. In the animals sacrificed later the periosteal layer of the diaphyses and growing cartilage were involved. In the animals sacrificed still later the deepest deposits appeared in the cortices. As the age of the animals advanced, metabolic activity lessened.

Diseased animals were also studied. In osteomyelitis the activity of deposit increased until the inflammatory processes subsided. In animals with transplanted Yoshida sarcoma, no deposit was seen in the tumor tissue itself, since it is non-osteogenic. In rickets, deposit was absent in the carti-

53. Tokushima University.
54. Kagoshima University.
55. Tokyo University.

laginous tissues and of little extent in the cortical layers. In experimental sciatic-nerve paralysis, despite marked bone atrophy, autoradiograms did not vary from the normal. After heavy doses of parathormone, spotting in visualized areas was found in both the epiphyseal plates and the cortical layers. In experimental adrenalectomy there was severe lack of calcium deposit.

Rate of excretion of calcium [46] was noted in the urine and feces.

Study of Bone Calcium Metabolism Using a Radioactive Isotope. Dr. Dazuo Sato [56] used a radioactive isotope to study fractures and their repair. There was increased metabolism, not only at the fracture site, but of all the bone structure involved.

Studies on the Cathodoluminography of Bones. Dr. Miyazaki [54] and Dr. Higashi used cathodoluminograms to study the distribution of rare trace elements in the ashes of rabbit and human bones. The luminescence obtained in normal bone structures appeared fairly evenly distributed. In human bones with pathological conditions the luminescence varied considerably, depending on the basic pathology. Malignant tumors seemed to reveal interesting and characteristic changes.

The Application of Ultrasound in the Diagnostic Field of Orthopaedic Surgery. Dr. Nishio [57], Dr. Shingu, Dr. Shimizu, and Dr. Yamada attempted to use flaws occurring in ultrasonic transmission as a method of diagnosis in certain orthopaedic lesions. The result, in general, was not satisfactory. In fractures, however, flaws in transmission were used advantageously to denote progress of union.

The Diagnostic Significance of Small Biopsy Specimens from the Ilium in General Osteopathy. Dr. Iino [7] and Dr. Wakamatsu studied biopsy specimens of the ilium of patients with postmenopausal osteoporosis. The degree of osteoporosis, as shown by roentgenogram, was either minimum, moderate, or excessive. Decrease in the number of trabeculae occurred as the lesions became more severe. In one patient treated by androgen and estrogen for one month, the tendency toward bone re-formation seemed to be definitely present.

Examination of Knee-Joint Temperature. Dr. Matsubayashi [58], Dr. Kumasaka, Dr. Kameda, and Dr. Suzuki used surface and intra-articular thermometric apparatus to perform experiments in the variation of temperature in knees. Changes in temperature in the knee joint were recorded after applying heat to the abdomen. By this procedure a normal standard was obtained.

The authors examined 271 patients with low-back conditions who had radicular findings in the lower extremities. A drop in temperature was demonstrated in patients with low-back conditions in whom there was sensory disturbance in a lower limb. The drop was maintained despite heating of the abdomen.

Electromyographic Evaluation in Kinesiology. Dr. Amako [18], Dr. Miwa, Dr. Tanaka, and Dr. Matoba said that they were unable to confirm the findings of Markee and associates, who said that muscles crossing two joints could act at either joint without influencing the other. Increased electrical activity appeared in the contraction rather than the relaxation phase. The authors were also unable to relate the peak of electromyographic change to actual shortening or lengthening.

An Application of Cineradiography in Kinesiology during Movement of the Cervical Spine. Dr. Suzuki [59], Dr. Tono, and Dr. Umehara made cineradiographs of the spine to show that a position of severe kyphosis or lordosis can obtain in falls. The authors believe that concussion of the spinal cord may take place, even when bone injury cannot be demonstrated, and so be the cause of subsequent symptoms.

Roentgenographic Study of the Ribs. Dr. Takagi [60], Dr. Ito, Dr. Tomoda, and Dr. Hashimoto described various trajectories of roentgen rays for use in diagnosis of rib lesions. Magnifying roentgenography, they believe, has been proved to be superior to ordinary methods.

Clinical Studies on Osteomyelography. Dr. Fugi [61] and Dr. Matsumoto injected contrast medium (urographin, 60 per cent) in the bone marrow to interpret intramedullary structure. The authors examined 108 clinical patients and noted characteristic findings in all. In bone tumors, spread of the medium was retarded by invasive lesions. Visualization of fractures was unsatisfactory. In osteomyelitis, early appearances were not reliable, but at later stages the material is

56. Central Railway Hospital.
57. Tottori University.
58. Tokyo Labor Accident Hospital.
59. Nihon University.
60. Nippon Medical School.
61. Osaka Prefectural Hospital.

obstructed by granulation tissue. In tuberculosis, passage was not retarded and frequently the material passed into a bone abscess or joint cavity. The extent of these lesions was better visualized by the method.

Clinical Study on Senile Osteoporosis with Special Reference to the Role of Estrogen. Dr. Miki [55] and Dr. Yokozeki made measurements of estrogen excretion in the urine in thirty-eight women from forty to eighty years of age who had entered the menopause. The patients were classified as having non-osteoporotic, slightly osteoporotic, or markedly osteoporotic conditions. Chemical findings were negative in all. After estrogen injections, its excretion was prolonged by severity of the lesion. Total protein increased, but other blood findings remained variable to unchanged.

Biochemical Study of Muscle Atrophy. Dr. Yamada [53] and Dr. Nozima studied quantitative changes of glycogen, creatine, potassium, chloride, sodium, and water in muscles atrophied from paralysis, arthritis, immobilization, and other causes. Changes were of the same type and extent regardless of the cause of muscle atrophy. There was a decrease in the intracellular components (glycogen, creatine, and potassium); an increase in extracellular components (sodium and chloride); and a slight increase in water content. Intensity of the changes are in direct relationship to gross atrophy and to histological findings.

Biochemical Studies on Muscle Disorders. Two Steps in the Breakdown of Incubated Adenosinetriphosphatase. Dr. Kawamura [16], Dr. Nakahara, Dr. Miwa, Dr. Yamada, Dr. Nakazawa, Dr. Toyama, and Dr. Yoshida said that the breakdown ratio of adenosinetriphosphatase incubated in whole blood is higher than when incubated in plasma. The presence of other adenosine nucleotides delays the breakdown of adenosinetriphosphatase. Adenosinetriphosphatase is dephosphorylated to adenosine diphosphatase, and then to adenosine monophosphatase, and finally to adenosine. This, the authors believe, is due to catalyzation by myokinase. Thereafter, adenosine is deaminated to inosine.

Cultivation of Synovial Tissues *in Vitro*. Dr. Kodama [17] and Dr. Okamoto cultured *in vitro* the synovial tissues from the knee joints of adult rabbits and of normal and rheumatoid human beings, and then determined the hyaluronic acid quantitatively. Appearing in culture were reticular tissue cells (fibroblasts) and mosaic tissue cells (epithelioid cells). The epithelioid cells were most concerned with the production of hyaluronic acid. The types of cells in cultured rheumatoid synovial membrane varied somewhat from the normal but not sufficiently to establish a definite pattern.

The Effect of Low Temperature on Bone and Cartilage in Tissue Culture. Dr. Amako [18], Dr. Tada, Dr. Maruta, Dr. Kitazima, and Dr. Kodama described the method of using the tissue cultures of the tibiae of chick embryos. The cultures were stored twenty-four hours at temperatures of from 5 degrees to −58 degrees centigrade.

Growth in length stopped in those specimens exposed to a temperature of −8 degrees centigrade; pH of the medium was lessened in proportion to the lowering of temperature. Fibroblastic outgrowth from the periphery of bone was maintained in all cases, except those specimens stored at a temperature of −58 degrees centigrade. Histologically, bone remained viable at any temperature, but many of the lacunae were empty and the nuclei of cartilage became pyknotic at temperatures lower than −8 degrees centigrade.

The Effects of Hyaluronidase on the Repair of Injured Organs. Dr. Kasuya [62], Dr. Hashikura, Dr. Nishi, and Dr. Morozumi found that hyaluronidase used experimentally in fractures in animals and in human beings does not give uniform results. Prolonged or repeated injection sometimes caused late induration and reaction.

The Effect of Age upon S^{35} Chondroitin Metabolism in Cartilage and Bone of Normal White Rats. Dr. Amako [18], Dr. Murakawa, and Dr. Takemitsu made histochemical studies of the metabolism of S^{35} after it was injected into normal white rats. Extensive tests were made from one week to twenty months after injection, at which time the animals were sacrificed. (The complete, original article may be obtained from the authors.)

Chondroitin Sulphuric Acid Content in Human Intervertebral Cartilage. Dr. Aoike [14] and Dr. Oda said that chondroitin sulphuric acid in human intervertebral cartilage is high in the embryonic stage and decreases with age. Decrease in content corresponds in degree with macroscopic degenerative changes. Although there is a higher content in the nucleus pulposus than the annulus fibrosus, the difference is not great.

Experimental Study on Viscosity of Synovial Fluid. Dr. Murisaki [28] and Dr. Kitazawa

62. The First National Hospital of Tokyo.

determined the changes that took place when the viscosity of the synovial fluid was reduced in a dog's knee. Twice a week, for a three-month period, three groups of dogs had their knees treated to reduce viscosity. Group 1 had an injection of hyaluronidase; Group 2 had an injection of isotonic sodium chloride solution; and in Group 3 synovial fluid was aspirated.

Articular cartilage in all three groups became thinner. In the group injected with hyaluronidase, thickening of the synovial membrane, subsynovial cell infiltration, and articular-cartilage damage were especially apparent.

A Study of Joint Effusion. Dr. Watanabe [63] and Dr. Ikeuchi studied effusions derived from aspirations of 1,408 joints. Investigations were made of turbidity, color, cell count and differential cell count, relative viscosity "spinnbarkeit" (described by Watanabe), specific weight, protein, mucin nitrogen, mucoid nitrogen, polysaccharide, and glucose. A new and rapid way of investigating viscosity was described by "parachute formation" of a droplet placed in copper sulphate solution. Dried effusion was examined by polarization microscope. Clinical application of the findings was not made.

A Biochemical Study on Synovial Fluid in Chronic Arthritis. Dr. Nishi [16], Dr. Mashiko, and Dr. Hirasawa made extensive studies of synovial fluid in relation to organic and inorganic substances. There was significant difference in biochemical findings between rheumatoid and other forms of chronic arthritis.

Pathological Synovial Fluid. Dr. Ikuo Nagaya [64] investigated synovial fluid of normal joints and those involved with infectious, traumatic, rheumatoid, and degenerative arthritis. A characteristic finding was the apparent relationship between elevation of fluid gamma globulin and severity of joint involvement.

Menkin's Factor in Arthropathy. Dr. Mizuno [9], Dr. Sima, Dr. Itikawa, Dr. Maturi, and Dr. Kawamura reported that in Menkin's factor secured from the synovial fluid of arthritic patients, they identified leukotaxine, necrosin, and exudate. When these were introduced in joints, they appeared to damage cells which, in turn, released further Menkin's factor, producing arthropathy typical of arthritis deformans, multiple rheumatoid arthritis, and neurogenic arthropathy. The authors proposed methods which may be of use in decreasing or stopping the action of Menkin's factor. They also suggested that there may be some justification for the actual implication of Menkin's factor in the conditions just mentioned.

Studies on the So-Called Itai-Itai Disease.* Dr. Fukazawa [65] and Dr. Murasawa said that itai itai disease has not yet been established as a definite clinical entity and that it is difficult to differentiate this condition from osteomalacia. The authors attempted to differentiate the condition from true osteomalacia, but final clarification of differential diagnosis is still impossible since cases of this disease are found in only one district of Japan. The problem is its localized regional occurrence, contrasted with the wide distribution of true osteomalacia.

* It is interesting to note that the name is derived from *itai*, a usual exclamation of pain in Japan, and denotes universal bone and joint pain and tenderness of extreme amount.

Sero-Immunological Studies on Rheumatoid Arthritis. Dr. Harada [66], Dr. Shichikawa, Dr. Takiuchi, Dr. Orihara, Dr. Tanabe, Dr. Maeda, Dr. Tamatani, Dr. Komatsubara, Dr. Inagaki, Dr. Matsubara, Dr. Yamamoto, Dr. Fujioka, and Dr. Hasegawa performed multiple agglutination tests on patients with rheumatoid arthritis; the results showed considerable inconsistency.

Histological Findings in Joints with Rheumatoid Arthritis, Adult Type. Dr. Mori [66], Dr. Onomura, Dr. Ogawa, and Dr. Bassho reported considerable change in findings between the acute phase of rheumatoid arthritis and the subacute or chronic stage. With the passage of the acute phase, the whole nature of the disease seems to change from the typical rheumatoid type of lesion to one of a chronic non-rheumatoid arthritic type.

Studies on Rheumatic Polyarthritis. Dr. Nakayama [67] and Dr. Murasawa reported isolation of *Streptococcus faecalis* and, by electron microscope, apparent flagellated cocci (beta-hemolytic) in rheumatic polyarthritis. The authors also discussed follow-up observations of patients treated by non-specific antimicrobial injection.

The Use of Steroids in the Treatment of Rheumatoid Arthritis. Dr. Watanabe [63] and Dr. Takeda observed thirty-five patients with rheumatoid arthritis who were on steroid therapy

63. Tokyo Teishin Hospital.
64. Nagoya National Hospital.
65. Kono Clinical Medicine Research Institute.
66. Mansai Medical School.
67. Kono Clinical Medicine Research Institute.

for from two to sixty-one months (average, twenty-three months). Steroid dosage was controlled mainly by erythrocyte-sedimentation-rate findings. In all patients the condition remained static during treatment. After cessation of treatment, however, only two patients remained free of complaints or findings. Relief lasted for twenty-seven months.

Pathology of Congenital Myogenic Torticollis. Dr. Matsumaru [68] and Dr. Tsuboi presented a series of cases of congenital myogenic torticollis and suggested that the most satisfactory results are obtained by those patients who were operated on early in the disease, with resection of the lesion.

Experimental Production of Skeletal Malformations. Dr. Hujimoto [69] and Dr. Hashizume injected insulin in varying amounts into 800 eggs, four to seven days after incubation. The experiment resulted in severe congenital variations and skeletal malformation.

The Effects of Prone Position on Respiratory Movement in Spine Operation: Presentation of a New Supporting Frame. Dr. Yamada [53] and Dr. Shichijo described the respiratory embarrassment resulting from the prone position of a patient being operated on for spine disease. The authors showed the various frames used for support and told of the final development of a new supporting frame.

Anesthesia Management of Orthopaedic Operative Patients. Dr. Yutaka Onji [25] analyzed various methods and medications for securing anesthesia in orthopaedic operations.

Arthroscopic and Histological Study of Tuberculous and Non-Specific Chronic Inflammatory Arthritis. Dr. Fukushima [70] and Dr. Matsumoto studied joints by arthroscopic methods and secured material for histological examination. Final diagnosis is dependent on histological study rather than gross appearance, although considerable knowledge of the extent of involvement can be gained through the arthroscope. Usually, a definite diagnosis can be made at this time.

Studies on Tuberculous Antibodies in Bone and Joint Tuberculosis. Dr. Kashiwagi [3], Dr. Kokubo, Dr. Sawamura, and Dr. Yokoyama did Mantoux tests on fifty-eight patients with bone and joint tuberculosis and twenty-two rabbits with experimentally produced tuberculosis. Both the affected and the uninvolved, symmetrical side were tested. The Mantoux reaction appeared to be stronger near the focus than on the healthy side. This reaction seemed to be influenced by non-specific factors, such as circulatory disturbance. The authors denied the concept that a more tuberculous antibody exists near the focus.

Experimental Researches on the Influence of Vitamin A on Bone and Joint Tuberculosis. Dr. Katayama [10], Dr. Itami, Dr. Onuma, Dr. Yamada, Dr. Kawada, and Dr. Yamamoto, in a controlled experiment, showed that diets deficient in vitamin A cause adverse effects in the treatment of animals with experimentally produced tuberculosis of the knee joint.

Changes in Vitamin A, B, and C, Serum Calcium, Phosphorus, and Alkaline Phosphatase Levels in the Blood in the Presence of Bone and Joint Tuberculosis. Dr. Katayama [10], Dr. Koizumi, Dr. Yoshikawa, Dr. Ohata, and Dr. Honda investigated ninety patients with tuberculosis of the hip or knee joint. All vitamin levels tended to decrease where there is continuous tuberculous activity. This was especially so where there were multiple joints involved or in acute stages of disease. There was a slight increase in alkaline phosphatase and gamma-globulin level in the blood. No significant relationship was found between the decrease in the vitamin levels and the serum calcium or phosphatase.

Experiments on Dissemination of Bacilli Causing Joint Tuberculosis. Dr. Nishi [16], Dr. Sampei, Dr. Harada, and Dr. Koizumi inoculated tubercle bacilli into the joints, liver, bone marrow, abdominal cavity, and intestine of animals and evaluated the time required for dissemination. Examination for detection of dissemination was made of the lungs and spleen at various intervals. Bacilli were recovered within five hours after inoculation into the liver or bone marrow. Abdominal inoculation required a little longer time. Bacilli in the lungs or spleen were shown within twenty-four hours after inoculations into the abdominal cavity and joints. Implantation within the intestine required three days before the bacilli disseminated. With inoculations into the joints no roentgenographic or clinical change occurred for from seven to ten days after demonstration of the bacilli in the lungs.

A Study of Experimental Knee-Joint Tuberculosis in Rabbits. Dr. Kashiwagi [3], Dr. Kokubo, Dr. Kataoka, Dr. Yokoyama, and Dr. Sawamura induced tuberculous changes in the

68. Nagoya University.
69. Shinshu University.
70. Juntendo Medical College.

knee joints of rabbits. They treated one group of rabbits with cortisone, another group with streptomycin, and a third group with cortisone and streptomycin. The greatest improvement was shown when cortisone and streptomycin were given together. The authors believe that this experiment may be of clinical use in the future.

Histological and Histochemical Studies of Calcified Foci in Bone and Joint Tuberculosis. Dr. Kondo [71] and Dr. Kato studied, by numerous staining techniques, the tissue from seventy-five patients with tuberculous bone and joint foci. The authors noted but little metachromatic change in the calcified areas. Alkaline phosphatase was intensely concentrated around the calcified area and much less within it.

An Experimental Study in Acceleration of Healing of Bone and Joint Tuberculous Foci Following Foci Débridement. Dr. Kondo [71] and Dr. Yamamoto inoculated the knees of guinea pigs with tuberculosis organisms. The findings indicated that under streptomycin therapy early or late débridement could be successfully carried out with other antibiotics (no antituberculosis drugs were used). Débridement in the active stage of the disease caused adverse sequelae in the control group.

The Effects of Kanamycin on Bone and Joint Tuberculosis. Dr. Katayama [10], Dr. Itami, Dr. Sato, Dr. Harada, Dr. Suzuki, Dr. Asahi, and Dr. Hasegawa treated tuberculous knees of guinea pigs with kanamycin and streptomycin. They then studied patients with tuberculous joints to whom they had given the two drugs.

With intensive treatment the results are similar with either kanamycin or streptomycin. However, with lower dosages and less frequent administration streptomycin is superior.

Operative Treatment of Bone and Joint Tuberculosis. Dr. Oda [72], Dr. Furuno, and Dr. Sakamoto performed 119 operations on tuberculous bones and joints during the past five and one-half years and found that the operation is most safely done during subsidence of the disease. Prolonged bed rest is necessary after curettement of spine caries. Curettage of the major joints, such as the hip, promotes more rapid recovery and results in less adhesions in adjacent joints. Constant evaluation of the liver should be made since liver function may be impaired, although involvement should not prevent treating specific bone or joint lesions. Concomitant care of any chest lesion is necessary.

Follow-up Studies on Operative Treatment of Hip-Joint Tuberculosis. Dr. Arihara [73] and Dr. Matumura reported on follow-up studies of ninety-one patients, sixty-seven of whom were operated on. Follow-up was from one to eleven years. Fifty-one of the patients had focal débridement, and only eight, arthrodesis. Subtrochanteric osteotomy was done in three patients, and curettement of the abscess in three. The last three procedures were done as operations for débridement of the hip. One patient died. Ninety per cent of the patients were healed to a point where they were socially rehabilitated. Ten per cent had poor results. Satisfactory motion and stability were not obtained in a badly destroyed joint.

End-Result Survey of Hip-Joint Tuberculosis Treated by Arthrodesis. Dr. Kono [28], Dr. Kawaji, Dr. Kurata, and Dr. Hotta reviewed forty-seven patients with tuberculosis of the hip joint on whom arthrodesis had been performed. Follow-up was from one to nine years. Twenty-six of the patients were children; arthrodesis failed in six on first operation, but in three there was solid fusion after the second attempt. The authors also discussed the question of deformity and shortening, and said that a solidly ankylosed tuberculous hip tends to prevent recurrence and enables the patient to work.

Dynamic Study Following Spine Fixation. Dr. Yasuda [74], Dr. Okada, Dr. Sasada, and Dr. Kitamura studied the transference of vibration in the lumbar spine with and without various forms of fixation. They noted no change in the transmission of vibration impulse.

A Study of Vertebral Tuberculosis Involving Extremely Severe Destruction and Loss of Tissue. Dr. Sakai [75] reviewed twenty-five patients with lesions involving the vertebral bodies, intervertebral discs, pedicles, posterior arches and, frequently, the transverse processes. The true extent of the lesions could not be appreciated from roentgenograms, or, indeed, from operative exploration. Full recovery to normal active status is impossible to obtain.

Vertebral Caries in the Aged. Dr. Nishi [16], Dr. Ebata, and Dr. Morita studied a series of patients, fifty years of age or older, with tuberculosis of the spine. The majority had their onset

71. Wafukai Medical Institute
72. National Kokura Hospital.
73. National Kyoto Hospital.
74. Kyoto Prefectural Medical College.
75. National Osaka Hospital.

at or after the age of forty. All gave a history of pleural involvement at some time before recognition of the spine lesion. The authors also reported findings made at six post-mortem examinations and concluded that prognosis was poor in this disease.

Bone-Grafting for Defects in Tuberculosis of the Spine. Dr. Imoto [76], Dr. Arima, Dr. Kimata, and Dr. Isida performed saucerization on 112 tuberculous patients on whom grafting of the defect was done on forty-two occasions. Twenty-eight of these patients had had co-existing pyogenic bacteria. In thirty-eight saucerization was done first; later, bone was implanted in the defects. The authors stated that only in one of these did recurrence take place. In four patients on whom a one-stage procedure was done, two needed reoperation.

Discussion of Patient's Position; Approach for Anterior Débridement of Thoracic Tuberculous Spondylitis. Dr. Okada [77], Dr. Iida, Dr. Tasaka, Dr. Matsugi, and Dr. Goto discussed the positioning of the patient and the wide incision made to gain an extrapleural approach to simplify operation.

Radical Treatment of Pott's Disease in the Thoracic Region by Thoracotomy. Dr. Kasai [78], Dr. Sasaki, and Dr. Tokutsu reported operating on eleven patients, ten with right thoracotomy and one with left. The anterior incision provided ease in approach, in removal of extensive diseased areas, and in implantation of anterior grafts.

Studies on the Cervico-Omo-Brachial Syndrome. Dr. Hattori [49], Dr. Oda, Dr. Ishikawa, and Dr. Tuda studied 124 cases of the cervico-omo-brachial syndrome with respect to blood pressure and skin temperature, in addition to making both roentgenograms and myelograms. The authors concluded that conservative care is best, and reported a 60 to 70 per cent improvement in such instances.

Roentgenographic Findings in the Cervico-Omo-Brachial Syndrome. Dr. Maeda [79], Dr. Tokunaga, and Dr. Iwanaga followed 225 patients with the cervico-omo-brachial syndrome and noted narrowing of the intervertebral foramen in 54 per cent (accentuated after the age of fifty). The authors compared the roentgenograms of the cervical spine of these patients with a control series of normal patients. Narrowing occurred most frequently at the third and fifth cervical spaces. At least two cervical spaces were involved in 80 per cent of the patients. Productive changes, as well as other findings, were also reported.

Myelographic Investigation of Disc Protrusion and Spondylosis in the Cervical Spine; Results of Surgical Treatment. Dr. Kondo [46], Dr. Ando, Dr. Omuro, and Dr. Tasaka operated on forty patients with cervical-disc protrusion and fourteen patients with cervical spondylosis, from 1947 through 1958. One patient had two disc protrusions. The authors reported the levels of protrusion, discussed the use of myelograms in diagnosis, described the operative procedure, and recorded the results. These were excellent in two patients, good in twenty, fair in nine, and unsatisfactory in ten. Four patients were worse, eight died, and one could not be followed.

Studies on Movement of the Lumbar Spine. Dr. Yamada [63] and Dr. Kondo carried out extensive experiments on anatomical specimens in regard to movement of the intervertebral joints in the lumbar area. These were checked by roentgenograms. The authors called attention to the similarity of the individual lumbar intervertebral joint in action to that of a diarthrodial-enarthrodial joint mechanism.

Experimental and Clinical Studies of the Lumbar Intervertebral Disc. Dr. Suzuki [80], Dr. Ishikawa, Dr. Sakamaki, Dr. Ogawa, Dr. Okano, Dr. Shiba, and Dr. Saito attempted to correlate the findings in clinical and histological examinations of patients with degenerative disc disease with the ruptured discs of cadavera. The authors reported the biochemical findings and concluded that there are still many unknown factors for the cause of pain in degenerative disc disease.

An Experimental Study on the Etiological Factor of Lumbar-Root Pain. Dr. Mizuno [9], Dr. Sima, Dr. Itikawa, Dr. Kawamura, and Dr. Matui discussed the possible etiology of lumbar nerve-root pain. Experiments on dogs indicated that inflammatory changes accompanying mechanical lesions and disc rupture could be a cause of such pain.

Electromyographic Studies on Patients with Herniated Lumbar Intervertebral Discs. Dr. Suzuki [80], Dr. Ishibashi, Dr. Okuda, Dr. Kanesaka, Dr. Sakamoto, Dr. Yama-

76. Momoyama Hospital, Osaka.
77. Kyoto Prefectural Medical College.
78. Kobe Central Municipal Hospital.
79. Kyushu Welfare Pension Hospital.
80. Chiba University.

zaki, Dr. Wakayama, Dr. Tomita, and Dr. Tateiwa did an intensive electromyographic study on patients with known herniated intervertebral discs. Where nerve-root pressure was demonstrable on clinical examination, definite changes in the electromyographic curve were also noted. As recovery from pressure took place, the curves tended to become normal. In certain instances the findings by electromyographic study did not correspond with the clinical findings, but such instances were rare.

The Etiology of Radicular Sciatic Pain. Dr. Yanagidani [81], Dr. Masuhara, Dr. Ozawa, Dr. Kashiwade, Dr. Iwatsubo, Dr. Otani, and Dr. Ono investigated radicular sciatic pain with electromyography and phlebography of the sinus tracts of the spine to clarify the mechanism of pain in the disc syndrome. In addition to compression another factor in pain is tension on the dura or dural extension. The authors also reported certain changes in the nearby venous structures but did not discuss these changes in relation to the production of pain.

The Treatment of Scoliosis. Dr. Matsuno [82], Dr. Nakabayashi, Dr. Nakamura, Dr. Takahashi, and Dr. Shirakawa described their method of treating scoliosis. The authors suggested certain modalities they believe preferable for the management of each type of lesion. They plan their follow-up report at a later date.

Role of the Leg Muscle in Supporting The Skeletal Structure of the Foot. Dr. Mizuno [9] and Dr. Yamasaki did an intensive study on the lower extremities of cadavera, measuring the application of force from the leg muscles. By roentgenograms, the authors noted deformity occurring subsequent to such applied force. They then correlated their findings with those in patients who had known specific muscle paralyses in their lower extremities.

The Use of Compound Resin in the Making of Artificial Hands. Dr. Takahasi [83] and Dr. Saino reported in detail the method of making artificial hands with compound resin and suggested that the hand is more elastic and durable and its appearance more natural.

An Investigation of Difficulties Encountered by Leg Amputees with Artificial Limbs. Dr. Ohneda [84], Dr. Kikuchi, Dr. Kitajima, and Dr. Takahashi found that the greatest difficulty experienced by amputees was owing to the development of severe perspiration of the stump and its ensuing complications. The authors measured the amputees' skin temperature during ordinary activity and while under excessive activity. They also measured the amount of perspiration per surface area between normal skin and the corresponding skin of the stump. At rest the stump had a lower temperature than the healthy leg, but on activity the reading became higher. Likewise, the perspiration was considerably higher on the amputated stump during severe activity. The authors noted that most of the amputees had devised ways of increasing their comfort, and that all such devices tended to aerate the prosthesis bucket, thus providing for removal of the excess moisture of the stump. They therefore suggested a new type of bucket for the prosthesis. The new bucket would provide ventilation for the stump, thus eliminating the present situation in which the socket acts as a poorly ventilated rubber boot.

Optimum Alignment of a Prosthesis and Its Effect on Gait. Dr. Ito [85], Dr. Imamura, and Dr. Arima studied gait by interrupted-light photography. The authors used a special suction socket and prosthesis, permitting changes in alignment of the prosthesis and variation in joint motion. There is a certain position of alignment and a definite range in joint motion (particularly hyperextension at the knee) which is optimum for each person. With the use of a prosthesis that would allow experimental alteration and observation of the patient's gait with interrupted-light photography, the best artificial leg can be provided for the individual patient.

An Experimental Study on the Prevention of Tendon Adhesions. Dr. Matsumaru [68] and Dr. Okumura discussed the use of cortisone in the prevention of adhesions after tendolysis. Cortisone is of considerable benefit, and five milligrams per kilogram of body weight should be given daily for fourteen days after tendon surgery.

Measurement of Finger Pinch. Dr. Hagiwara [86] devised an electrical measuring apparatus for the recording of single and multiple finger pinch and of lateral pinch power.

Changes in Bone and Other Organs on an Excessive Administration of Diphenylalanine. Dr. Sadamu Hotomi [87] experimented with four groups of white rats. One had a basic

81. Osaka University.
82. Hokkaido University.
83. Takaoka Hospital.
84. Gunma University.
85. Kansai Rosai Hospital.
86. Tokyo Medical College.
87. Wakayama Medical College.

diet, a second the same diet with ten times the minimum amount of phenylalanine, a third a basi diet with estrogen administration, and a fourth a phenylalanine-excess diet and estrogen.

The changes previously noted with excess phenylalanine in the diet, such as thinning of articular cartilage and changes in the pituitary and ovarian systems, appeared to be prevented when there was simultaneous injection of estrogen. On histological study of the ovary, adrenal, and hypothalamus there appeared to be definite antagonistic action between phenylalanine and estrogen. The question was raised as to whether this action would have some application in the treatment of collagen diseases.

A Method of Assessing Skeletal Age. Dr. Matsumaru [63] and Dr. Nakazawa made roentgenograms of the wrists and hands of 4,293 children between the ages of four to seventeen years. Since individual bones show different aging processes in the same person, the ages of all bones in the wrists and hands were scored; the average denoted the skeletal age of the child. This is a more accurate system than just noting the findings in one or two bones.

Tissue-Culture Study on Growth and Calcification of Chick Embryo Bone. Dr. Miki [56], Dr. Shimimu, and Dr. Kabata said that their study involved three separate observations: (1) Bone growth in synthetic media TC-199 (DIFCO) was less than in ordinary media composed of chick-embryo extract, horse serum, and Gey's salt solution; (2) With CA [45] autoradiographic study on calcification indicated that radioactivity itself had no influence on growth ratio. Precipitation of CA[45] was accelerated by the addition of sodium chloride or horse serum through the culture media; and (3) Inhibition of bone growth by antigen-antibody occurs with addition of even small amounts; when the whole serum of culture media is replaced by antiserum growth ceases entirely.

Hormonal Effects on the Growth of the Body and Bone of the Chick Embryo. Dr. Iino [7] and Dr. Yamaguchi injected parathyroid hormone into one group and follicle hormone into another group of hens' eggs and noted changes in weight, length of the femur, and mortality rate. Histological studies were made of the femur in each of the groups. Parathyroid hormone accelerated weight and growth in lower dosages and slightly inhibited them in higher dosages. Follicle hormone stimulated ossification throughout, it inhibited weight gain and bone length, and caused considerable degenerative histological changes within bone-marrow structure, particularly in the higher concentrations. Mortality rate was increased by both hormones, especially at higher concentrations.

An Experimental Study on Long-Bone Growth. Dr. Iwahara [6] and Dr. Koyama, in experiments with rabbits, drilled, redrilled, and fractured the shaft of the long bones. Transient overgrowth occurred after drilling and repeated drilling could again accelerate growth. After fracture, growth was inhibited for two weeks and then overgrowth occurred, especially five to seven weeks later. Overgrowth was controlled by partial premature closure of the epiphysis. In the ultimate results there was no essential difference in the length of the bones treated.

Experimental Study on Epiphyseal Stapling in Long Bones. Dr. Iwahara [6] and Dr. Machino reported on the deformities occurring from stapling of the distal femoral epiphysis in rabbits. Staples were placed at various locations and the alteration of growth occurring incident to the staples was compared with changes occurring when the staples were at other locations.

Experimental Study in Dislocation of Hip Joints and Reparative Processes Occurring. Dr. Tukushima [88] and Dr. Fujiyama dislocated the hips of young rabbits by closed manipulation. Because the findings in this experiment resemble those seen in congenital dislocation of the hip in children, the authors believe the results may be suggestive of the etiology of this condition.

Changes Occurring in Congenital Dislocation of the Hip. Dr. Mizuno [9], Dr. Simazu, Dr. Ebara, Dr. Yuba, and Dr. Ayai reviewed a study made of 187 patients, from ten months to forty years of age, with congenital dislocation of the hip. Roentgenographic, histological, and clinical findings showed that progressive changes occur throughout numerous structures and become irreversible at an early age. The authors described minutely the changes that occur in all the structures.

Secondary Changes Occurring in Congenital Dislocation of the Hip. Dr. Iwahara [6] and Dr. Suzuki believe that many of the changes noted after treatment of congenital dislocation of the hip occur not from the dislocation, but from the treatment. The authors dislocated the hips of young hares and examined them twenty-four weeks later. The animals with the hips still dislocated had very small acetabuli and large, flat femoral heads; those in which the heads had been replaced showed only slight coxa valga. In a group in which the acetabular margin had been shaved off, the hips were extremely unstable, the acetabuli very large, and the femoral head uneven

88. Juntendo University.

in outline. The authors concluded that early and adequate reduction of dislocated hips is essential in children.

Roentgenographic Study of the Development of the Hip Joint in Growing Children. Dr. Kotake [89], Dr. H. Mizuno, and Dr. T. Mizuno studied the roentgenograms of 922 children between the ages of one and seventeen years with respect to the developing osseous structure of the hip apparatus. The findings have been published and are available on request.

Influence of the Season at Birth on Development of the Hip Joint of the Infant. Dr. Mizuno [90] and Dr. Hotta indicated in a somewhat philosophical discussion that there is a difference in the development of the iliac portion of the pelvis in the infant born during the cold season. This, if true, could have some bearing upon the etiology of congenital dislocation of the hip.

Congenital Dislocation of the Hip: Articular Mechanism and Relationship to Arthrochalasis Multiplex Congenita. Dr. Takagi [60], Dr. Hasue, Dr. Nakano, and Dr. Oka listed criteria for the diagnosis of arthrochalasis multiplex congenita. When this condition exists, they believe that it has definite influence on the development of a congenitally dislocated hip.

Early Diagnosis of Congenital Dislocation of the Hip. Dr. Koizumi [91] and Dr. Hara studied, roentgenographically, 650 infants from new-born to six months of age. The authors compared these roentgenograms with those of eighty-five children with unilateral dislocation of the hip and thirty-one with bilateral dislocation. They noted certain changes in the pelvis with regard to rotation and development, which are usually typical of dislocation and which may be helpful in establishing a diagnosis in a questionable case.

A Critical Study of Indirect Radiography of the Hip Joint for Early Diagnosis of Congenital Dislocation. Dr. Nagai [92] and Dr. Ozawa studied 6,157 infants during 1958; 5,084 had normal hips, 951 were unclassifiable, and 122 (2 per cent) had dislocated hips.

In 144 of the 951 unclassified infants studied by a new roentgenographic technique—so-called indirect radiography—the authors found three more dislocated hips and were still uncertain in forty-nine.

The authors therefore believe that their new method of roentgenographic examination is valuable. (The original article can be obtained on request.)

Spontaneous Re-position of Congenital Dislocation of the Hip Joint.* Dr. Ueda [93], Dr. Ueke, and Dr. Ando examined 2,486 infants and found 165 with dislocation of the hip. One hundred of these infants, two to four months old at the time of first examination, were not treated but observed, with roentgenograms made monthly. Spontaneous re-position occurred in seventy-eight of the untreated infants, generally when they were from three to ten months old. Season of birth, prematurity, and nutritional state showed no relationship to the self-cure.

Results of Treatment of Congenital Dislocation of the Hip in Infants. Dr. Ayani [94] and Dr. Ota treated 106 infants under one year of age with congenital dislocation of the hip. Results were good in 33 per cent; fair in 54 per cent; and poor in 13 per cent of the infants. The best results were obtained by closed reduction and diaper or splint immobilization.

Results in Treatment of Congenital Dislocation of the Hips and the Relationship to Nutritional Status and Growth. Dr. Akabayashi [95], Dr. Sudo, and Dr. Shibata treated eighty-two infants with congenital dislocation of the hip and feel certain that there is a definite relationship between the end result and the nutritional status of the infant during its care.

Results of Treatment of Congenital Dislocation of the Hip in Infants. Dr. Tanno [96], Dr. Furuno, and Dr. Mukasa between 1948 and 1955 saw 520 infants with congenital dislocation of the hips. The authors reported their results, which confirmed that early treatment is imperative.

A Procedure for Congenital Subluxation of the Hip Joint (Subchondral Arthro-

* In Japan the children are frequently carried on the mothers' backs, with the legs straddled.

89. Nagoya University.
90. Nagoya University.
91. Gunma University, Maebashi.
92. Tokyo Medical College.
93. University of Nagoya.
94. Gifu Prefectural Medical School.
95. Sendai National Hospital.
96. National Kokura Hospital.

plasty). Dr. Kaubara [97], Dr. Matuo, Dr. Masumoto, Dr. Sasao, Dr. Ogawa, and Dr. Kuramoto discussed a modification of Colonna's capsular arthroplasty, giving full credit to Dr. Colonna. The authors described the operative procedure and said that their results have been good. Horizontal pelvic osteotomy is not a good procedure, at least in their hands, because of developing incongruity of the hip joint.

Operative Treatment of Congenital Dislocation of the Hip. Dr. Mizuno [9], Dr. Wada, and Dr. Miyauchi reviewed the various forms of surgical treatment for congenital dislocation of the hip and reported their results.

Subtrochanteric Osteotomy and Femoral Lengthening. Dr. Miyagi [98], Dr. Yamada, Dr. Shin, Dr. Matsufiji, Dr. Kawasaki, and Dr. Soejima reported the procedure, complications, and results of subtrochanteric osteotomy performed on forty-five patients for attempted femoral lengthening. The average gain in length was 1.6 centimeters.

97. Saiseikai Nakatsu Hospital.
98. Kurume University.

REFERENCES

Flexor Pollicis Longus Muscle

(Continued from page 470)

1. Humphry, G. M.: Observations in Myology. Cambridge and London, Macmillan and Co., 1872.
2. Kaplan, E. B.: Correction of a Disabling Contracture of the Thumb. Bull. Hosp. Joint Dis., 3: 51–54, 1942.
3. Kaplan, E. B.: Functional and Surgical Anatomy of the Hand. Philadelphia, J. B. Lippincott Co., 1953.
4. Testut, Léo: Les Anomalies Musculaires chez l'Homme Expliquées par l'Anatomie Comparée. Leur Importance en Anthropologie. Precédé d'une Préface par Mathias Duval. Paris, G. Masson, 1884.
5. Testut, Léo, and Latarjet, André: Traité d'Anatomie Humaine. Ed. 8. Paris, Gaston Doin, 1928.

News Notes

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Seventy-third Annual Meeting of The American Orthopaedic Association will be held at the Homestead, Hot Springs, Virginia, May 30 to June 2, 1960, under the Presidency of Dr. John R. Moore. The tentative program of the Meeting, as submitted by the Program Committee, is as follows:

Monday, May 30

Morning Session

Myelodysplasia.
Leonard F. Bush, M.D., Danville, Pennsylvania.

Spondylolisthesis: Etiology and Comparative Efficacy of Various Surgical Procedures.
L. L. Wiltse, M.D., Long Beach, California.

Spondylolisthesis and Tight Hamstrings.
George S. Phalen, M.D., Cleveland, Ohio;
James A. Dickson, M.D., Cleveland, Ohio.

Surgical Treatment of Spondylolisthesis.
Arthur A. Thibodeau, M.D., Boston, Massachusetts.

Bone Density Evaluation in Relation to Orthopaedic Management.
C. Fred Ferciot, M.D., Lincoln, Nebraska.

Introduction of the Exchange Fellows.
J. W. Dickson, F.R.C.S., Great Britain;
R. H. C. Robins, F.R.C.S., Great Britain;
J. H. S. Scott, F.R.C.S. (Edin.), Great Britain;
A. H. C. Ratliff, F.R.C.S., Great Britain;
W. G. Doig, F.R.C.S., Melbourne, Australia.

Executive Session

Evening

The President's Reception.

Tuesday, May 31

Morning Session

Aneurysmal Bone Cyst.
William F. Donaldson, Jr., M.D., Pittsburgh, Pennsylvania.

Pigmented Villonodular Synovitis with Invasion of Bone.
Paul E. McMaster, M.D., Beverly Hills, California.

Eosinophilic Granuloma 'One of Three Sisters'.
Charles R. Rountree, M.D., Oklahoma City, Oklahoma;
Charles A. Rockwood, Jr., Capt. USAF (MC) (by invitation).

Sarcoma in Paget's Disease of Bone.
Hugh C. Barry, F.R.C.S., F.R.A.C.S. (by invitation), Sydney, Australia.

The Pathology of the Pseudofracture and Its Correlation with Clinical Disease.
Ira H. Rapp, M.D., Charlotte, North Carolina.

Guest of Honor
Henry L. Jaffe, M.D., Pathologist, Hospital for Joint Diseases, New York, N. Y.
Diagnostic Problems Raised by Myositis Ossificans and Other Lesions.

Evening

Cocktail Party.

Wednesday, June 1

Morning Session

Prognosis in Fractures of the Acetabulum.
Carter R. Rowe, M.D., Boston, Massachusetts;
J. Drennan Lowell, M.D. (by invitation) Boston, Massachusetts.

Open Reduction and Traction in the Treatment of Fracture Dislocations of the Thoracic and Thoraco-Lumbar Vertebrae with Spinal Cord Injury.
J. Gordon Petrie, M.D., Montreal, Canada.

Diaphyseal Fractures of the Major Long Bones. A Clinical Study of Healing after Plating.
Floyd H. Jergesen, M.D., San Francisco, California.

Complete Dislocation and Subluxation of the Acromioclavicular Joint: End Result in 70 Cases.
Patrick J. Kelly, M.D. (by invitation), Rochester, Minnesota;
Marco A. Lazcano, M.D. (by invitation), Mexico City, Mexico;
Sanford H. Anzel, M.D. (by invitation), Shaw Air Force Base, South Carolina.

Injuries of the Medial Ligaments of the Ankle—Result Study.
O. Sherwin Staples, M.D., Hanover, New Hampshire.
Presidential Address.
John R. Moore, M.D., Philadelphia, Pennsylvania.

Evening
Cocktails.
Annual Banquet and Ball.
Guest of Honor
John P. Stapp, Col., USAF (MC), Chief, Aeromedical Space Laboratory, Wright-Patterson Air Force Base, Ohio.

Thursday, June 2

Morning Session
Anterior Chamber Angle of the Eye in Patients with Idiopathic Scoliosis.
Ignacio V. Ponseti, M.D., Iowa City, Iowa;
Gunter K. Von Noorden, M.D. (by invitation), Iowa City, Iowa;
Herman M. Burian, M.D. (by invitation), Iowa City, Iowa.
The Problem of the Primary Curve.
John R. Cobb, M.D., New York, N. Y.
Surgical Instrumentation for Management of Scoliosis.
Paul R. Harrington, M.D. (by invitation), Houston, Texas.
Birth Injuries of the Brachial Plexus.
Jack Wickstrom, M.D., New Orleans, Louisiana.
Hip Pathology in the Patient with Cerebral Palsy.
Lenox D. Baker, M.D., Durham, North Carolina;
Richard Dodelin, M.D. (by invitation), Durham, North Carolina.

Second Executive Session.

MUSCLE AS A TISSUE

November 3 and 4, 1960
The Lankenau Hospital
Philadelphia, Pennsylvania

Thursday, November 3
Morning Session: Basic Aspects of Structure and Functional Anatomy of Muscle.

Chairman: Clark E. Brown, M.D., The Lankenau Hospital.
Introductory remarks and historical background by the Chairman.
1. The Skeletal Muscle. Andrew F. Huxley, M.A., Cambridge University, England.
2. The Smooth Muscle. Emil Bozler, Ph.D., Ohio State University.
3. The Cardiac Muscle. Robert W. Ramsey, Ph.D., Medical College of Virginia.
4. Discussion.

Afternoon Session: Muscle Contraction.

Chairman: H. E. Huxley, Ph.D., University College, London, England.
Introductory remarks by the Chairman.
1. Biochemistry of Muscle Contraction. Andrew G. Szent-Györgyi, M.D., Institute for Muscle Research, Massachusetts.
2. Chemical Events and Contractile Activity. Robert E. Davies, Ph.D., and Dennis F. Cain, Ph.D., University of Pennsylvania.
3. Contractivity of Models and Relaxation Factors. Laszlo Lorand, Ph.D., Northwestern University.
4. Energy Expenditure in Muscle Contraction. Britton Chance, Ph.D., University of Pennsylvania.
5. Discussion.

Evening Session: Dinner.

Address: A prominent Russian scientist has been invited.

Friday, November 4
Morning Session: Muscular Performance.

Chairman: David B. Dill, Ph.D., Army Chemical Center, Maryland.
Introductory remarks by the Chairman.
1. Muscular Performance. Erling Asmussen, Ph.D., University of Copenhagen.
2. Muscular Training and Fatigue. E. Höhwü Christensen, Ph.D., Fysiologiska Institutionen, Stockholm.

3. Cardiac Performance. Steven Horvath, Ph.D., The Lankenau Hospital.
4. Capacity of Smooth Muscle. Stewart G. Wolf, M.D., Oklahoma.
5. Discussion.

Afternoon Session: Clinical Application.

Chairman:
Introductory remarks by the Chairman.

1. The Cardiac Patient. George E. Burch, M.D., Tulane University.
2. Muscle Tone and Postural Regulations. Ragnar Granit, M.D., The Nobel Institute for Neurophysiology, Stockholm.
3. The Pharmacology of Muscle Relaxants. Stuart C. Cullen, M.D., University of California Medical Center.
4. The Aging Muscle and Its Work Capacity. Kaare Rodahl, M.D., The Lankenau Hospital.
5. Discussion and summary by the Chairman.

Evening Session: Open forum.

Chairman: Edward L. Bortz, M.D., The Lankenau Hospital.

1. Physical Fitness in Health and Disease—with demonstrations.

The Part II examination for Certification by the **American Board of Orthopaedic Surgery** will be held January 4 through 6, 1961, at the Americana Hotel, Bal Harbour, Miami Beach, Florida. Sam W. Banks, *Secretary*, 116 South Michigan Avenue, Chicago 3, Illinois.

The Spring Meeting of the **New Jersey Orthopaedic Society** will be held on Tuesday, May 17, 1960, in conjunction with the Orthopaedic Section of the New Jersey State Medical Society, Haddon Hall, Atlantic City, New Jersey. The topic of the meeting is A Symposium on the Injured Knee.

The chief editors of the **Excerpta Medica Foundation** announce the beginning of a recorded medical journal to be issued under the title *Voice of Medicine*. It will be devoted to recordings of discussions and interviews taken during national and international medical congresses, clinical-pathological conferences, world health assemblies, medical meetings, and symposia.

The **Second International Course of Lyophilization** will be held from August 29 through September 9, 1960, in Lyon, France. The course has been arranged for those who are using the freeze-drying technique: research workers in the biological and botanical sciences and those engaged in experimental and clinical surgery. Courses will be presented in French and English by a distinguished faculty, including Dr. A. S. Parkes of the National Institute of Medical Research, London, Professor R. I. N. Greaves of Cambridge University, and Dr. H. T. Meryman of the Naval Medical Research Institute, Bethesda, Maryland. The course of lectures will cover every phase of freezing and drying, theory, applications to the preservation of biological products, foodstuffs, possibilities for the preservation of whole organisms, and projected future trends. Participants will have the opportunity of practical exercises with a great variety of apparatus. Full details concerning the Second International Course of Lyophilization, including costs, living accommodations, and registration, may be obtained by writing Dr. Louis R. Rey, Directeur des Cours Internationaux de Lyophilisation, Laboratoire de Physiologie, Ecole Normale Superieure, 24 rue Lhomond, Paris 5e, France.

The **Exchange Fellowship Committee** of **The American Orthopaedic Association** is now inviting applications from American orthopaedic surgeons who are interested in the tour to Great Britain in the Spring of 1961. The requirements are: The applicant must be under forty years of age as of December 1, 1960; he must have completed Part 2 of the American Board of Orthopaedic Surgery examinations; and he must be a citizen of the United States. Requests for application blanks should be made to the Chairman of the Exchange Fellowship Committee, Dr. J. Neill Garber, 806 Hume Mansur Building, Indianapolis, Indiana.

The next deadline for application for grants by the **Orthopaedic Research and Education Foundation** is May 1, 1960. Applications received after that date will be deferred until January 1961. Application blanks may be obtained from Harold A. Sofield, M.D., *Secretary-Treasurer*, Orthopaedic Research and Education Foundation, 29 East Madison Street, Chicago 2, Illinois.

KAPPA DELTA AWARD—1961

The Committee on Scientific Investigation of The American Academy of Orthopaedic Surgeons announces that all manuscripts which are to be submitted for the Kappa Delta Award, which is presented annually for the outstanding scientific contribution in the field of orthopaedic surgery and which carries an honorarium of $1,000.00, should be received by June 15, 1960. Manuscripts should be forwarded to the Chairman, Robert D. Ray, M.D., University of Illinois College of Medicine, 840 South Wood Street, Chicago 12, Illinois.

The winner of the award will be asked to present his paper at the Annual Meeting in January 1961.

An opportunity for intensified study of important recent advances in electronics and other fields of instrumentation and their application to the fields of medicine and biology is to be offered by the Massachusetts Institute of Technology during the coming summer. The **Third Bi-annual Course on Modern Research Methods in Biology and Medicine** is to be held July 5 to 15, 1960.

The Special Summer program will be of particular interest to medical research workers and biologists as well as to research administrators. The material in this course will be presented in the form of Instrumentation Elements. This method of teaching offers considerable advantages over older methods. Knowledge of higher mathematics is not a prerequisite for the course.

Instrumentation has led to revolutionary developments in many of the physical sciences; it will be of similar importance in the life sciences, leading to new research methods and diagnostic procedures.

The 1960 program will be under the direction of Dr. Kurt S. Lion, Associate Professor of Applied Biophysics; lectures will also be given by specialists from Massachusetts Institute of Technology and other universities.

All facilities at Massachusetts Institute of Technology will be open to the members of this course, and housing will be available in the Institute's dormitories.

Application forms and full information may be obtained from Dr. James M. Austin, Director of the Summer Session, Room 7-103, Massachusetts Institute of Technology, Cambridge 39, Massachusetts.

The **Eighth Congress** of the **International Society of Orthopaedic Surgery and Traumatology** will be held at the Hotel Astor, New York, N. Y., September 4 through 9, 1960. For information write: Lee Ramsay Straub, M.D., 535 East 70th Street, New York 21, N. Y.

DISCUSSION

The Cytodifferentiation of Osteoblasts

(Continued from page 498)

does? Do osteoblasts undergo mitosis? Do the authors have chemical analyses to substantiate their suggestion that the cellophane dialyzes the fluid media?

The normal product of osteoblastic activity is calcified bone. In tissue culture, the end product has been described by others as preosseous tissue, osteoid or chondro-osteoid. If it is not calcified it should at least be calcifiable in suitable media before it can be proved to be the normal end product of the osteoblast. To prove the identity of the cell, Dr. Rose and Dr. Shindler might produce bone by either excision of the explant or transplantation of the outgrowth to a favorable location in a living animal.

No laboratory method, not even one as glamorous and fascinating as tissue culture, is any better than the purpose for which it is used. If the purpose is to study the morphology and histochemistry of osteoblasts, it might be better to leave the cells in the chick embryo. If the purpose is to isolate osteoblasts and study the conditions leading to osteogenesis, there is much to learn from tissue culture. It would be important to know the effects of altering the culture media, including such changes as the amount and kind of the amino acids, the carbon dioxide-oxygen tension, the relationships between the various organic and inorganic chemical components—both anions and cations and the buffers (phosphate and carbonate). Biomechanical factors, such as pressure (extrinsic and intrinsic), tension, and torsion, also require further study.

Dr. Rose and Dr. Shindler have perfected a beautiful technique for tissue culture of chick-embryo endosteum. They are now in an excellent position to devise experiments on the biochemistry of osteogenesis.

Book Reviews

LECTURES ON INTERPRETATION OF PAIN IN ORTHOPEDIC PRACTICE. Arthur Steindler, M.D. Springfield, Illinois, Charles C. Thomas, 1959. $18.50.

This outstanding and much needed book is the swan song of a giant. Arthur Steindler was truly one of the greatest orthopaedic surgeons of all time. He lived a long life and was alert and productive to the end. If we would dare wish for more, it would be that he could have lived to see the publication of this final book. He would have been well pleased with it. He always enjoyed seeing his books broaden the wide horizon of his teaching.

There can be no disagreement that the interpretation of pain deserves more interest on the part of investigators. It must take its rightful place alongside other modalities of clinical investigation. In the locomotor system, orthopaedic situations are reflected by three prominent features: (1) deformity, (2) dysfunction, and (3) pain. Of the three, pain is by far the most difficult to interpret and to evaluate. Steindler has shown that more meticulous interpretation of pain can be highly rewarding. He emphasizes that an analysis of pain in the early stages of an entity may lead to a recognition of the process while it is still reversible and while more effective methods of treatment can be instituted.

The analysis of pain is presented, first, on the basis of the anatomical structure involved, such as joints, muscles, and bones, and second, on the basis of anatomical regions, such as the thoracic spine, the lumbosacral junction, and the upper extremities.

Dr. Rudolfo Cosentino of Argentina did the anatomical dissections for the book. These remarkably skillful dissections, beautifully photographed and reproduced, add a great deal to the value of the book. The physical qualities of this treatise are outstanding.

Considerable attention is given to the wide variation of individual patients in their reaction to a given pain stimulus. Pain unfortunately cannot be measured objectively. For the most part it remains subjective. The need for achieving maximum communication with the patient in learning about the pain is emphasized. To quote Dr. Steindler: "Every effort should be made to establish in the sea of complaints, the actual pathological stratum." A systematic method of achieving this goal is outlined. To quote Dr. Steindler further: "Pain speaks its own language. It may be crude and inarticulate, according to linguistic standards, but it assumes diagnostic meaning by such accessory facts as intensity, quality, duration and consistency."

In some of his earlier books, the style of writing was ponderous; in this book, he has achieved a delightful fluency. This is the first classic on pain since Hilton's. Steindler in this fine treatise takes his place with Hilton as a classic apostle of Rest and Pain.

The book is written primarily for orthopaedic surgeons, but will be of broad interest to general surgeons, internists, and general physicians.

J. Vernon Luck, M.D.

BONE AS A TISSUE. Edited by Kaare Rodahl, M.D., Jesse T. Nicholson, M.D., and Ernest M. Brown, M.D. New York, McGraw-Hill Book Company, Inc., 1960. $16.00.

During the last decade studies of bone as a tissue have utilized an increasingly large variety of laboratory techniques. It is impossible to select from the medical and biological literature an adequate practical sample which reveals the advancing state of knowledge in this field. Certainly no single journal has particularly devoted itself to basic studies of mineralization, bone structure, and the like. Investigators interested in the various disciplines which contribute to the field have found it convenient to present their experimental observations at special conferences, such as those of the Josiah Macy, Jr. Foundation on Metabolic Interrelations and, more recently, The Gordon Research Conferences on The Chemistry, Structure, and Physiology of Bones and Teeth. The present volume is a collection of the papers and the discussions which followed them at the 1958 Annual Research Conference of the Lankanau Hospital in Philadelphia. A group of authorities in different fields of research relating to bone were invited, and their contributions provide a valuable summary of a selection of topics all pertaining to bone, considered structurally, physiologically, and, to a very minor degree, clinically. The contributions are listed according to four categories—each a fragmentary exposition covering the interests of the four investigators represented on each segment of the program: (1) osteoporosis, (2) dynamics of calcium metabolism, (3) ultrastructure of bone, and (4) vitamin D, parathyroid glands, citric acid, and phosphorus metabolism.

The book cannot be considered either a primer or a textbook for advanced students. Once the reader has an understanding of the techniques and the scope of the problems, the collection may serve the valuable function of providing supplemental recent information on the topics listed. The outstanding value of the book is in the setting forth of different theories and interpretations of the evidence on several problems which are of importance to all interested in bone and bone disease. For example, the evidence pro and con for dietary or hormonal or other etiology of osteoporosis is given in the first section. In the second the question of the exchangeable fraction of bone mineral with relation to blood calcium is given in clear and readily understandable terms and a new interpretation, by Marshall, constitutes perhaps the outstanding new idea in the book. The different ideas of how matrix is related to collagen are also discussed. All in all the book is a fine compilation of many heterogeneous topics nearly all of which can serve to advance the basic knowledge of orthopaedists and students.

Jonathan Cohen, M.D.

BURN CARE . . . *a case study*

St. Mary's Hospital
Milwaukee, Wisconsin

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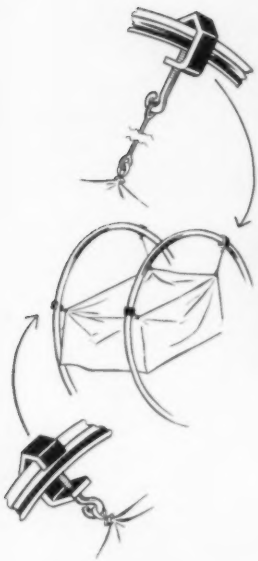

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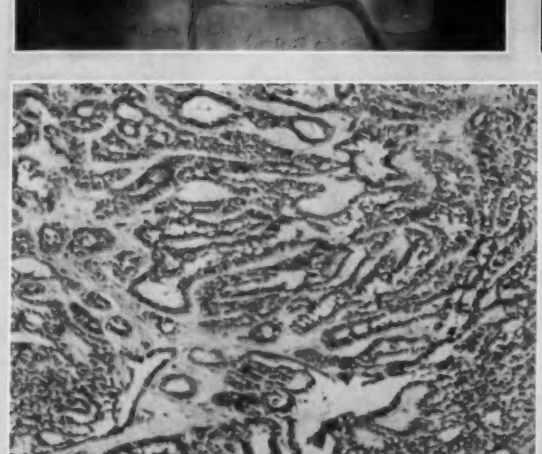

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Radiograph *(upper left)* showing an adamantinoma in the lower end of a tibia in a man of 48 years. The lesion has caused lytic destruction and expansion of the contour of the affected part of the bone.

Photograph *(upper right)* of frontal section of specimen. The adamantinoma tumor tissue was clearly demarcated from the spongiosa. It was tough and firm but presented small areas of cystic degeneration.

Photomicrograph (x 90) *(left)* showing the alveolar glandular pattern so characteristic of certain fields of an adamantinoma.

Turn page for data on Osteogenic Sarcoma.

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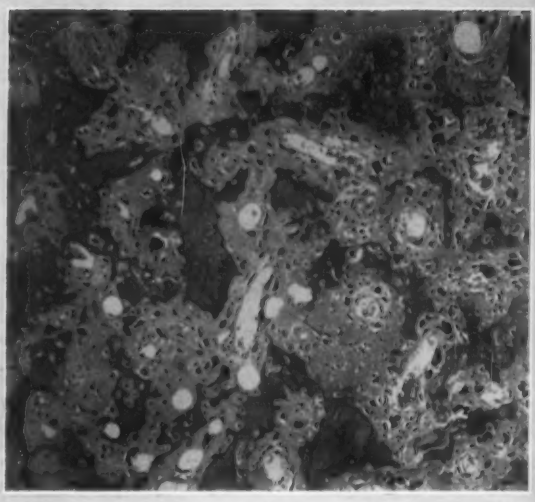
Photomicrograph (x 70) *(right)* showing an osteogenic sarcoma tissue field in which a considerable amount of calcifying intercellular material has been laid down between the tumor cells.



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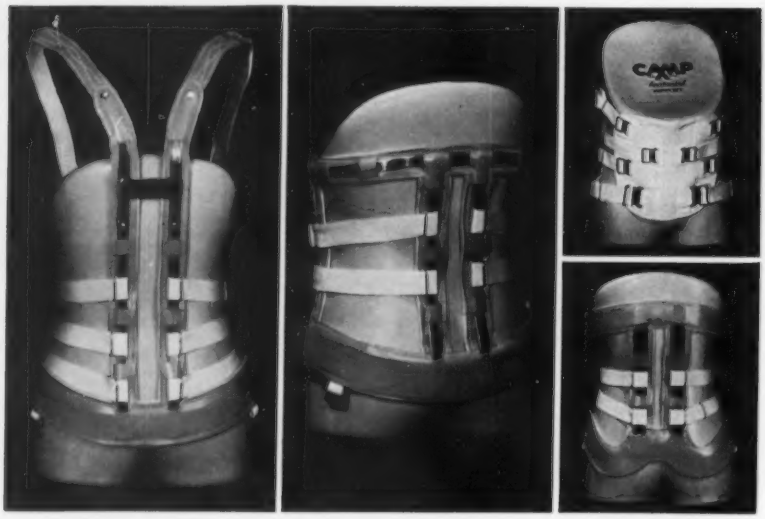

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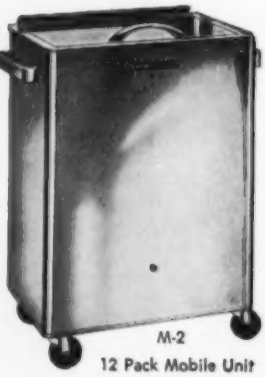

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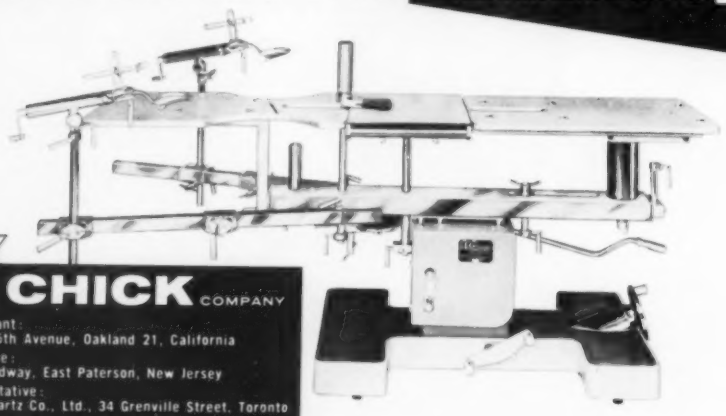

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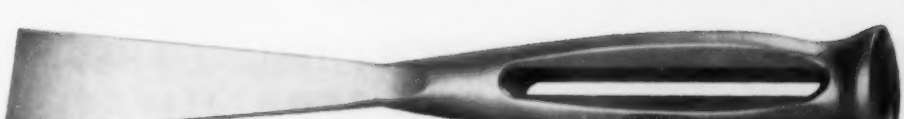

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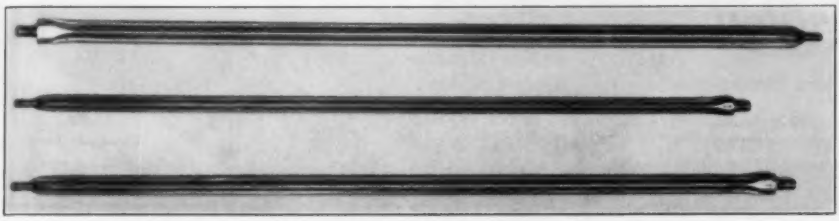

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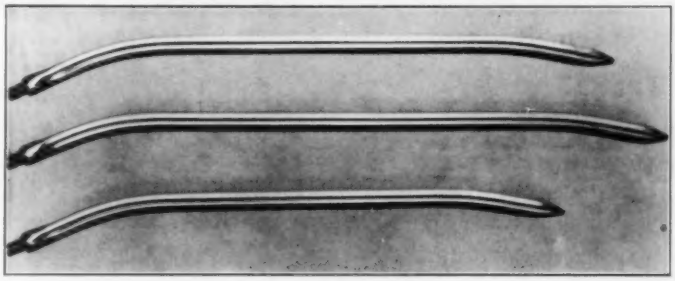

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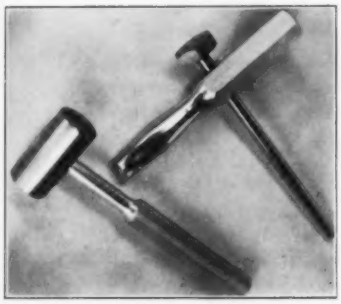

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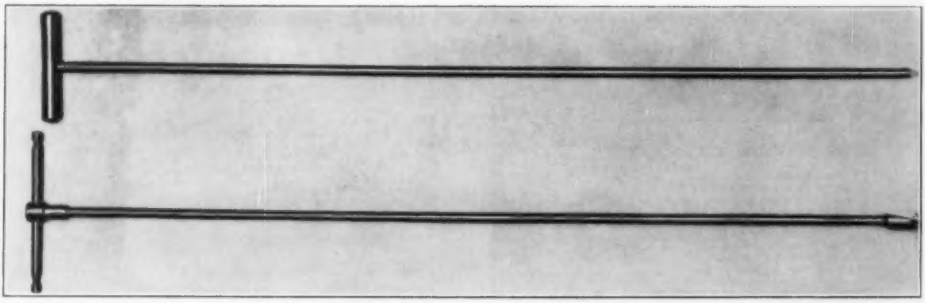

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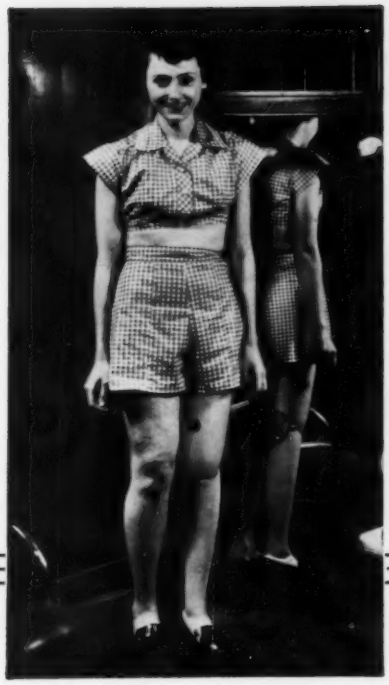

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